Church Music Monographs

THE CHURCH ORGAN

NOEL BONAVIA-HUNT, M.A.

Stuart W. Artless.

The Organ.

The Church Organ. By Noel Hunt. "Church Music Monograp[illegible]" (Faith Press.) — There are probably quite a number of expert musicians who could not give a reasonably lucid description of that finest of musical instruments, the organ, and who thereby fail to exploit its possibilities to the best advantage. It is for such as these that Mr. Hunt writes. His book is a work of reference which will be useful, we imagine, to all who have anything to do with the organ, though he disclaims, in his modest way, having anybody in his mind save the "humble seeker for information"—he does not attempt to instruct the organ-builder or professional expert. All that need be said here is that his arrangement is excellent and his expressions clear and to the point, and that he supplies a series of admirable illustrative diagrams. Not least of his merits is the furnishing of a serviceable index.

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THE ORGAN.

IN what is no doubt the finest historical novel ever written—I refer of course to Charles Reade's "The Cloister and the Hearth"—I seem to remember reading about a priest who was so concerned with building himself an organ, that he feared that such interest must be a snare of the devil. I do not know whether the Rev. Noel Bonavia-Hunt has ever actually built an organ, but after reading his book, "The Church Organ" (Faith Press, four shillings and sixpence), I feel sure that if he was wrecked on a desert island *à la* Swiss Family Robinson, he would at once begin to erect a truly magnificent specimen out of the kegs, tubs, and domestic animals obligingly and inevitably strewing the strand. And this would be a loss to England, for it is the writer's invariable experience, wherever he goes, to find organists proudly showing off their stops "voiced by Bonavia-Hunt, you know." And this building of an organ is not so very difficult, and is extremely fascinating. In my father's house in Devonshire there is a specimen of my own work, built while still in the 'teens, which I am always going to bring up to London, but never manage to do so. . . . But I digress.

The style of this book is clear, simple and concise, and the illustrations are arranged on two or three sheets which open out like maps, and thus enable the reader to always have them under his eye. It is thoroughly up-to-date, and the only thing I, personally, was disappointed in was the way the author denied me a full explanation of the Hope-Jones Diaphone. The printing and paper are excellent, and make one look forward to many more of the now well-known Church Music Monographs. The book is well worth more than the moderate price asked, and should be on every musician's—aye, and mechanic's—bookshelf.

One word of warning to the tyro who tries to tune his organ according to the directions on page 84—the first D in the second bar should surely be a sharp.

C. À BECKET WILLIAMS.

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THE CHURCH ORGAN

CHURCH MUSIC MONOGRAPHS

1. **THE CHORALES.** A. W. Wilson, M.A., Mus.Doc., Organist of Manchester Cathedral.
2. **THE CHURCH ORGAN.** Rev. Noel Bonavia-Hunt, M.A.
3. **BYZANTINE MUSIC AND HYMNOGRAPHY.** H. J. W. Tillyard, D.Litt.
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CHURCH MUSIC MONOGRAPHS

EDITED BY THE REV. H. V. HUGHES, M.A., Precentor of the Society of the Faith

No. 2

THE CHURCH ORGAN

AN INTRODUCTION TO THE STUDY OF MODERN ORGAN-BUILDING

BY

THE REV. NOEL A. BONAVIA-HUNT, M.A.

PEMBROKE COLLEGE, OXFORD

"Scientia artem adjuvat"

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PREFACE

THE author's sole intention in producing this little volume is to provide the organ-lover with an introduction to the study of organ construction and tonal architecture, with the hope of spurring him on to the acquirement of a profounder knowledge of this fascinating subject. This book is not therefore written for the instruction of the organ builder or the professional expert, nor does it in any respect claim either to be an exhaustive treatise or to reveal any sensational discoveries. Having strictly in mind the humble seeker after information, the author has concentrated his literary efforts on a clear and simple presentation of the fundamental principles of modern organ design, of which an intelligent grasp is the key to the mastery of one of the most intricate of sciences.

He wishes to acknowledge his deep obligation to his friend Mr J. T. H. Burrell, A.M.I.C.E., for his assistance in preparing the illustrations, without which a work of this kind would be shorn of half its value.

N. B. H.

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THE CHURCH ORGAN

CHAPTER I

THE WIND-PRODUCING PARTS

THE Organ is a musical instrument, whose pipes (which produce the sound) are supplied with wind under pressure. It will be our first aim to give the reader some insight into the complex structure of the various parts of this wonderful machine (evolved after many centuries of gradual development), which enables the player at the keys to control many hundreds of pipes.

1. THE BELLOWS.—This is a wind-collecting apparatus, consisting of (*a*) *feeders*, which collect a quantity of atmospheric air and enclose it in a (*b*) *reservoir*, placed immediately above them, which receives and stores the wind for the purpose of after-distribution. The top-board of the reservoir is *weighted*, and the wind is thus compressed and propelled through trunks to the sound-boards on which the pipes stand. All modern reservoirs are horizontal in form, and are constructed as in Fig. 1. In this illustration the usual " double rise " is shown, consisting of two series of ribs, the upper fold being inverted in order to neutralise the action of the lower. These, together with the counter-balances or regulators which keep the folds at an equal distance apart and thus ensure the required interaction of the upper and lower pairs of ribs, guarantee a steady and equal supply of pressure-wind.

Single-rise reservoirs are frequently used when there is difficulty of height to contend with, and the wind-distribution is then equalised and steadied by means of stout spiral springs fixed at each corner of the top-board ; indeed, springs may also be employed to take the place of the surface weights. Speaking generally, however, the double-rise

reservoir is the best, because it is very difficult to adjust the springs to a nicety.

The action of the bellows is as follows :

As the feeder drops (*i.e.* expands) the atmospheric air throws back the bottom-board valves, and rushes through the holes thus exposed into the feeder itself, and fills the cavity of the feeder with air ; here it remains imprisoned by the re-closing of the bottom-board valves. The feeder is next drawn up (*i.e.* contracted), and this action causes the imprisoned air to press up against the underside of the middle-board. The valves controlling the holes in the middle-board are thus in their turn forced back, and the wind is free to pass up into the reservoir. The middle-board valves now re-close and prevent the wind returning into the feeders, so that the top-board of the reservoir is compelled to rise (the ribbed folds expanding) in order to accommodate the storage of wind. At the same time the weights on the top-board are pressing it down and resisting the influx of wind, which is propelled through the various trunks (or canals) to the several departments of the organ. As the wind (under pressure of the surface weights) escapes through the trunks, the reservoir gradually collapses until a fresh supply of outside air is drawn in by the feeders. It will be readily seen that the ribs of the reservoir are subjected to a continual strain from the simultaneous pressure exerted from below and above them (*i.e.* from the feeders and the surface weights), consequently the upper and lower folds are separated by a floating *middle-frame* which acts as a support to both and keeps them in their proper positions.

There are two kinds of feeder in use, the hinged and the horizontal square-drop feeder. The former of these is that almost always provided for hand-blowing, as being the easiest to work. Two hinged feeders are usually supplied to the reservoir and operated by a lever, the one ascending while the other descends (see Fig. 1). But for large organs, especially with heavily weighted reservoirs, the square-drop feeder is undoubtedly the best, because it is capable of supplying at least double the quantity of wind at one stroke compared with that of the hinged type. Three of these feeders controlled by a revolving three-throw crank are capable of adequately supplying any size of reservoir, but it is necessary to employ mechanical blowing in this case (see Fig. 2), and a few words on this subject will not be out of

place. The two most popular forms of mechanical blowing are by water and by electricity, indeed no other form of power should be employed except as a last resort. The hydraulic engine is perfectly satisfactory where there is a mean pressure of thirty pounds or more to the square inch, and provided that a constant supply can be guaranteed. As the engine is noiseless it can be planted in the organ itself and directly connected to the feeders, and the amount of water used is exactly proportional to the amount required. For efficiency, noiselessness and economy, this form of power blowing is hard to beat.

The electric motor, so far as power is concerned, is quite as efficient as the hydraulic engine, but as the current supplied is in some districts "continuous" and in others "alternating," the method of installation must be adapted accordingly. Where the supply of current is continuous the three-throw crank and feeder method is the best, because it can be worked by a comparatively low speed motor inside the organ without making any noise. As everyone knows, the demands which the player makes on the wind are very unequal, varying in accordance with the stops he uses; consequently the speed of the electric motor requires to be self-regulating, and this with the continuous current is effected by some form of resistance introduced into circuit. If a wire resistance is used, it is connected to the top-board of the main reservoir by means of a chain; if a water resistance, the top-board is similarly connected to a plunger suspended in a jar. The resistance, in either case, increases with the rising of the reservoir, causing the motor to revolve more slowly, while the reverse takes place when the reservoir falls. Where the supply of current is alternating, this method of automatic regulation is not possible, and if the crank and feeders are used, regulation of speed can only be effected by means of a belt drive with a fast and loose pulley, the latter receiving the belt when little or no wind is demanded. A far more popular method of supplying the reservoir with wind in the case of an alternating current is by means of a revolving fan, which blows the air direct to the reservoir through a trunk. When the reservoir is full, the fan, though it continues to revolve at top speed, ceases to supply any wind. The fan can, of course, be employed with a continuous current, but as it is a very noisy contrivance, and has to be placed at some distance from the organ, it should only be resorted to when the crank and feeder system is impracticable.

In large organs, a single reservoir would be hopelessly inadequate, and every first-class builder makes it a rule to provide a separate reservoir for at least each manual sound-board. These reservoirs are supplied by a main reservoir; that is to say, each of these reservoirs is connected to the main by a trunk, and their rise is controlled by a pallet (placed either in the well of the reservoir or in the supply-trunk), which closes and cuts off the wind supply from the reservoir as its rise reaches a certain point. Thus each reservoir can be weighted to give its own pressure of wind to a sound-board, provided that the pressure be below that of the main reservoir.

The main reservoir requires a waste pallet (or safety valve) to prevent it from being forced too high by accident, as, for instance, when the manual blower continues to pump air into it after it is full, or when, in the case of mechanical blowing, the automatic regulating device goes wrong. The waste pallet is fixed in the top-board, and may be constructed to open either outwards or inwards when the reservoir is full, thus allowing the superfluous air to escape.

The pressure of wind employed in an organ may vary from 1 in. to 50 in. The most usual limits are 3 in. to 20 in. The actual pressure is ascertained by means of an anemometer or wind-gauge (see Fig. 3). This is supplied with water and substituted for one of the pipes on a given sound-board, and the corresponding key is depressed (the stop having been previously drawn), and the wind passes up the foot of the gauge and forces the water up one side of the bent glass tube, causing the deviation between the two surfaces shown in the illustration. The difference is measured by an inch-rule and corresponds with the wind-pressure, which is marked in inches.

The size of the bellows required to supply wind to a given number of stops may be calculated to a nicety by the mathematician. The old rule of allowing two square feet of reservoir for each stop is not by any means a safe one. The ideal bellows is infinite in area, but for practical purposes it is quite easy to calculate a satisfactory size on the principle of two and a half to three square feet per stop supplied by the reservoir, allowing 20 strokes per minute for the operation of the feeders.

2. The Trunks.—These have already been mentioned as the canals (or conduits) through which the compressed air is propelled from

the reservoir to the sound-boards. They are generally made of wood and rectangular in shape (for the sake of convenience), though the smaller trunks can be and often are cylindrical in shape and made of metal. Long and tortuous trunks should be avoided if possible, and this is one reason why each manual should be supplied by its own reservoir placed just below the sound-board. The trunking can then be short and direct. When the trunks are long and the reservoirs too small, it is customary to attach a "concussion bellows" to the trunk in question, which has the effect of steadying the wind. As will be seen in Fig. 4, this concussion bellows resembles a small feeder controlled by a spring.

Another contrivance which affects the wind in its passage through the trunk to the sound-board is the tremulant, a modern form of which is shown in Fig. 5.

The pressure chamber is filled with wind from a small cylindrical trunk taken from the main trunk which supplies the sound-board. When the disc-valve A moves up (this movement is controlled by the draw-stop), the motor B collapses and pulls down the pallet C, thus admitting wind to the upper chamber. The wind immediately rushes into the top bellows or motor D, which is inflated and simultaneously lifts up the pallet E. The top motor finds its wind-supply cut off, while the wind it has just received escapes through the exhaust vent F. The top motor collapses only to receive a fresh supply through the pallet re-opening, with the result that the top motor rises and falls in rapid succession and causes the wind in the trunk, sound-board and pipes affected to vibrate. The slide G regulates the quantity of wind admitted to the upper chamber, while the tapped wire H regulates the stroke of the pallet E. The vibrato beat of a tremulant should be carefully adjusted so as to be neither too quick nor too slow.

3. THE SOUND-BOARDS.—These (also called "wind-chests") are machines which distribute the compressed wind to the pipes.

The old-fashioned sound-board consists of the following parts:—(*a*) the *wind-chest* which, supplied with wind from the reservoir as previously stated, stores it in reserve for distribution among the pipes standing on (or connected with) the sound-board. It is, actually, the reservoir or pressure chamber of the sound-board. Next, situated immediately above the chest, comes (*b*) the *groove-chamber* (or wind-

groove), which is an upper chamber divided by bars into grooves, thus presenting the appearance of a grid. These grooves are normally destitute of pressure-wind, pallets (fitted with springs) being fixed between the chest and the grooves to control the admission of wind to the latter. There is a pallet to each groove, and a groove to each key, and the depression of a key means the opening of its corresponding pallet which admits wind to the groove.

The roof of the groove-chamber is called (*c*) the *table*, and this is bored with holes through which the wind is intended to pass to the pipes standing above. On the top of this table is placed a series of sliders also pierced with holes—one slider for each stop of pipes standing on the sound-board—and immediately over the sliders comes (*d*) the *upper board* pierced with holes corresponding with the holes in the table. The foot of each pipe stands on these upper board holes, and when a key pallet admits wind to a groove, it only requires the drawing of the slider to permit the wind to pass through the table and upper board holes to the corresponding pipe of that particular stop. The holes of the slider do not correspond with the holes of the table (below) and the upper board (above) until the slider is drawn (*cf.* the "hit or miss" vent).

In order that the pipes may stand securely in an erect position, a (*e*) *rack-board* is fitted directly over the upper board, pierced with holes of sufficient diameter to accommodate the pipe-feet about 4 in. or so above the foot-hole, and this rack is supported upon small wooden pillars. This description of the different parts of a sound-board must be read in connexion with Fig. 6. Although it is called the "old-fashioned" type of sound-board, it is still regarded as the best form for general use, especially when it is desired to plant a number of stops of pipes on one sound-board. A glance at Fig. 6 will show that the pallets do not extend right to the back of the sound-board. If they did, they would have to be as long as the groove they control, and this would make them absurdly heavy. Consequently, the bars are covered with leather or American cloth from the point where the pallets are hinged to the back end of the groove-chamber (*i.e.* the rear end of the chest). It should be noted also that the pallets and springs are accessible for repairs by removal of the face-board.

Another type of sound-board, which is essentially a pneumatic one, is known as the "sliderless and barless" chest, and is shown in Fig. 7.

In this the pallet, instead of being pulled down, is lifted up, and every pipe on the sound-board has its own separate pallet, whereas on the old-fashioned barred sound-board one set of pallets controls the wind supply to all the stops planted on it. A barred sound-board holding a dozen stops, for instance, would be fitted with as many pallets as there are notes on the keyboard, say 61, while the barless chest holding the same number of stops would require 61×12 pallets, *i.e.* 732. Each stop of pipes is separated off from the others, just as if they were all planted on separate sound-boards, and these air-tight compartments have their own separate draw-stop action. The wind-chest for each stop is practically a trunk, which is only supplied with pressure-wind when the stop is drawn and opens a large pallet (or "ventil") admitting the wind. The key pallets of these sound-boards are usually circular valves made as light as possible. There are many varieties of the sliderless chest, of which examples can be found in practically every organ built, each builder favouring his own pattern, but the governing principle is in all cases the same. Two notable types are the "Kegellade," which enjoyed a large vogue in Germany, so named after the conical shape of its pallet-valves, and the Roosevelt, which is shown in Fig. 8 *a*, *b*. The advantages of the type over the slider chest may be summed up as follows:

(1) As each pipe has its own pallet, no wind can pass from one pipe hole to another, as in the case of the sliders. If the latter do not fit accurately the wind will leak through (or "run") to other pipes in the same series, and this is a most irritating defect.

(2) Each pipe has its own wind-supply, therefore its speech is not affected by the number of stops drawn, as is so liable to be the case with slider sound-boards.

(3) The draw-stop action is simpler, because instead of the troublesome slider, there is only a pallet to be opened. With a *number* of stops to be controlled, this means greater facility in the application of combinational arrangements.

(4) The duplication and extension of various stops is rendered easier and certainly less costly, as, if it is attempted with the ordinary barred sound-board, a separate pallet-box and action has to be provided for each stop of pipes so treated, and this

does not make for economy of either space or expense. (See Chapter VI., p. 102.)

There are, however, two objections to the barless sound-board.

The first is the difficulty of obtaining access to the pallets. It is true that the latter very seldom give trouble, but if they do, either all the pipes have to be removed from the sound-board, and the upper board unscrewed and taken off in order to get at them, or else if the bottom-boards are detachable, the action to the pallets has to be disconnected. No sound mechanic would ever design a machine that is difficult of access for repairs, and consequently, from an *engineering* point of view, the barless sound-board, if it contains more than two stops, is liable to adverse criticism.

Secondly, the absence of the groove-chamber deprives the pipes of the air-cushion provided by the barred slider sound-board, each stop of pipes being supplied through a separate set of channels or grooves. The advantage of this air-cushion is one that has been pointed out by acousticians as materially affecting the speech and tone of the pipes, so much so that it may even be said to constitute the sound-board proper. The tenor, middle and treble octaves of flue stops appear to be most of all benefited by the time-honoured groove-chamber, and its absence is more noticeable on a large sound-board containing several stops.

The conclusion at which one may reasonably arrive after a close comparative study of the two types of sound-board is this—if a sound-board is to supply a number of stops, the barred slider type is to be preferred, although the maximum number of stops permissible on one chest should be eight; while if the sliderless chest be used, not more than *two* stops should be planted on it, a detachable face-board being provided at either end.

Where it is desired to make two separate sound-boards for the purpose of using two different wind-pressures or for departmental transmission, valuable space can often be saved by constructing *one* barred sound-board and dividing it into two sections by means of a cross-bar fixed in the groove-chamber. A set of pallets can then be provided at either end of the chest, and access can be had to them by removal of the face-boards at either end (see Fig. 9). In this way the great or swell sound-board can be constructed so as to hold

light-pressure flue-work and heavy-pressure reeds, both being transferable to other claviers if desired. (See Chapter VI., p. 100.) The sliderless chest serves excellently for pedal stops, for pipes planted off the main sound-boards (such as front pipes), or for a manual stop treated on the unit system. (See Chapter VI., p. 101.) A very simple sliderless chest, designed for this special service, is shown in Fig. 10. Having described the passage of the pressure-wind from the bellows, through the trunks, to the sound-boards and so to the pipes themselves, our next subject must be the means by which the wind to the pipes is controlled by the player at the keys, in other words the *action* of the organ. This subject falls under two headings: *A*, the control of the *notes*, or key action; *B*, the control of the different ranks of pipes, or draw-stop action.

A. The Key Action.—There are four principal kinds which we have to consider:

(1) the tracker;
(2) the pneumatic lever;
(3) the tubular-pneumatic;
(4) the electro-pneumatic.

(1) The *tracker action* is the oldest and most direct method of control, as by its means the player's finger to all intents and purposes pulls down the sound-board pallet in depressing the key. The mechanism is absurdly simple, as can be seen by a glance at Fig. 11.

The key itself is really a lever, so that when the player's end is pressed down the other end is raised. On this other end (or "tail end") is fixed a small upright circular rod $\frac{3}{8}$ in. in diameter, known as the "sticker," and the top of this is connected to another lever (a horizontal one, called the "backfall"). The tail end of the key being raised as before mentioned, the anterior end of the backfall is also raised, which means that the other (posterior) end is lowered. To this latter the sound-board pallet is connected by means of a "tracker" (a vertical strip of wood, usually $\frac{5}{16}$ in. by $\frac{1}{8}$ in. and varying in length according to circumstances) fastened at its top end to a wire (called the "pull-down") which passes through the bottom-board of the wind-chest and is connected to the pallet itself. Consequently, the lowering of the posterior end of the backfall lever pulls down the pallet in the sound-board, and this admits the wind stored in the wind-chest to the

pipe. When the key is released, these movements are reversed, allowing the spring under the pallet to return it smartly home.

This is the action of one single key ; but in dealing with the action of a number of consecutive keys the method of arranging the parts must naturally be adapted to the method of planting the pipes on the sound-board. In any case, the sound-board is wider than the manual, and even if the pipes are planted in semitonal order, *i.e.* in the same order as the keys of the manual, only the stickers can be arranged parallel with the keys, while the backfalls must radiate out in fan formation in order that their back ends may keep in line with the pallet pull-down. If, however, as is nearly always the case in modern organs, the pipes are planted tonally, with the bass pipes at either end of the sound-board and the smaller pipes in the middle (*i.e.* CC, DD, EE, FF♯, etc., being planted on the right and CC♯, DD♯, FF, GG, etc., on the left), then the back end of each backfall is connected to one of a set of horizontal rollers (of wood or iron). These rollers are provided with an arm at either end, one arm being connected with the back end of the backfall, the other being connected with the pallet pull-down. Thus the CC key on being depressed will lower the back end of its backfall *and* the left hand arm of the roller placed in direct line with it, while the right hand arm of the roller will pull down the pallet some eight feet to the right. By employing a number of these rollers of varying lengths and fixing them in due order to a frame known as the "roller-board," *all* the keys can be connected with their corresponding pallets.

The objections to tracker action are (*a*) that it makes the touch too heavy in an organ of any size, especially when the couplers are in use, and when heavy wind-pressures are employed (this heaviness of touch being due to the fact that the pallets have to be pulled down *against* the pressure-wind in the wind-chest), and (*b*) that the movements become noisy in course of time through the friction of the parts. The consequence is that tracker action is fast becoming obsolete except for quite small organs.

(2) The problem of lightening the touch of a large organ was tackled in the early part of the nineteenth century. Various forms of "relief-pallet" were introduced (by Messrs Hill, Holt, Jardine, and Willis respectively), by means of which the pallet was split into two sections and pulled down by instalments, so to speak. But this palliated rather

than solved the difficulty. A very ingenious form of relief-pallet was also applied which paved the way to the introduction of the modern form of pneumatic action, but this will be described in its right place.

The *pneumatic lever action* was introduced by C. S. Barker in 1832, and marks the transitional stage through which organ key action passed from tracker to tubular-pneumatic. From the key to the backfall the action was unaltered, but a small bellows or motor either replaced the old tracker or was interposed between the back end of the backfall and the tracker.

The introduction of the *motor*[1] marks an important epoch in the evolution of organ mechanism It is a small bellows. Two small pieces of wood are placed on the top of each other and joined together by thin leather in such a manner that when pressure-wind is introduced the leather is inflated, thus moving the top-board (the movable part). Fig. 12 shows (*a*) the hinged motor which opens and shuts like a reporter's note-book, and (*b*) the circular motor which opens and shuts to an equal extent all round.

The *raison d'être* of the motor is to create either a backward and forward or an up and down movement. Take the hinged motor, and bore a hole into its bottom-board. Place your mouth to the hole and blow through it. Immediately the top-board rises (the motor being inflated), and directly you stop blowing or remove your lips from the hole the motor collapses and the top-board falls down to its normal position. If instead of merely removing your lips from the hole you were to suck the air out of the hole, the motor would collapse even more forcibly. If the motor is held upside down, the top-board falls down and the motor remains open and suction would be required to shut it; but if the top-board happens to be connected with some resisting body (such as a pallet held by its spring), the motor remains in the closed position, and on being inflated with sufficient force the bottom-board falls down, thus dragging down the resisting body with it. Another point to notice is that when a hinged motor is inflated, the top-board acts as a *lever*, the hinged end *falling* while the other end *rises*, though not, of course, to the same degree. Hence the hinged motor was originally called a "pneumatic lever."

One of the best forms of the pneumatic lever key action is shown

[1] Introduced in a practical form by Joseph Booth of Wakefield in 1827.

in Fig. 13. It is a modification of the Barker model by Cavaillé-Coll of Paris.

The tracker A pulls down the square B, which moves to the left valves E and Q, thus unclosing the hole F and closing the hole P. The chamber D is continuously supplied with pressure-wind by a trunk from the reservoir, while T and K are ordinary atmospheric chambers. Pressure-wind rushes through the hole F and up through the hole G into the motor M and blows it up, raising the near end of the backfall S and pulling down its rear end and with it the sound-board pallet pull-down V. When the key is released the positions of the valves E and Q are reversed, cutting off pressure-wind from the motor M and allowing it to exhaust into atmosphere through the hole L, and thus closing the sound-board pallet. The smartness of this return movement is ensured by the spring N, which is tensioned outwards. The valve W controls the upward movement of the motor M. The leather purse C enables the horizontal trace-rod H to move through the pressure-chamber D without interfering with its air-tight condition.

This system works admirably when the distance between the keys and the sound-boards is not great, but otherwise the amount of tracker work required becomes a distinct disadvantage.

(3) The desire for the elimination of all long and unwieldy trackers led to the invention of *tubular-pneumatic action*.[1] Part of this action is directly connected with the keys and placed immediately behind the console, and part of it is directly connected with the sound-boards and placed immediately below them. These two parts are connected by narrow metal tubes (similar to gas pipes) of varying length, the diameter ranging from $\frac{1}{4}$ in. to $\frac{7}{16}$ in.

Let us first of all deal with the sound-board part of the mechanism. In all pneumatic actions the sound-board pallet is pulled down and returned home by the movement of the top-board of a motor (as in the lever-pneumatic action).[2] If the motor is placed upside down, the top-board (now underneath) will have to drop down to pull open the pallet, and therefore the motor will have to be *inflated* (as in Fig. 19). If,

[1] The pneumatic action applied by David Hamilton in 1835 to the organ in St John's Episcopal Church, Edinburgh, is the precursor of nearly all pressure systems since introduced.

[2] Reference is not here made to the application of pneumatic action to the type of sliderless sound-board described on p. 15, where the pallet opens *upward*.

on the other hand, the motor be placed right way up (as in Figs. 15 and 16), it must be made to *exhaust* (or be deflated) to enable the top-board to descend. This motor, whose function it is to open and close the sound-board pallet, is technically called the "main" or "primary" motor. In order that it may be powerful enough to control the pallet, this main motor must be somewhat larger in area than the pallet, and it can be placed either *inside* or *outside* the wind-chest. If placed inside the chest, it must be made to exhaust; if outside, it can be made to exhaust or, if reversed, to inflate.[1] The idea of placing the main motor *inside* the wind-chest and causing it to pull down the pallet by exhausting was probably suggested by an ingenious form of relief-pallet designed by some long-forgotten mechanic. A small motor is placed on the floor of the wind-chest directly underneath the pallet (see Fig. 14). The pull-down wire is passed through this motor and fixed to its top-board by a button. On depressing the key, the tracker closes the motor and pulls down the pallet at the same time. Very little pressure is needed on the key to perform this movement, as a hole is bored through the bottom-board of the chest into the underside of the motor, and the motor is thus enabled to exhaust into outside atmosphere; indeed, it is only kept open by the resistance of the pallet spring. Thus the only pressure required is that required to neutralise the resistance of the spring.

Now examine Fig. 15.

Here we have the same motor (suitably enlarged) fixed to the floor of the wind-chest and connected by a wire to the pallet above. The motor is kept open not only by the pallet spring but also by *being in a state of inflation*, pressure-wind being supplied to it through the channel *a a*. A glance at the disc-valve *b* will show the reader that its movement controls the situation. If pushed up it effectually closes the wind-chest and prevents any pressure-wind entering the motor. At the same time the hole *c* is unstopped and all the pressure-wind in the motor escapes through this hole into outside atmosphere, thus causing the motor to collapse and pull down the pallet. The return of the disc-valve to the position shown in the illustration allows the wind in the chest to re-inflate the motor and so close the pallet.

[1] It can, of course, be made to inflate upwards, as in Fig. 13. Several of the Vincent Willis types are arranged thus (see p. 23).

Our next question is—How is the disc-valve controlled? And the answer will be found in Fig. 16 *a*. Here we see the disc-valve raised by the inflated motor *d*, which is made as small as possible (*i.e.* just large enough to lift the valve with the given wind-pressure). This little outside motor (known as the auxiliary motor) is supplied with pressure-wind through the pneumatic tube E as soon as the key is depressed. Instead of a hinged motor, a circular motor can be used, or else a membrane (see Fig. 16 *b*), which is an inflatable purse or cap of leather covering a supply hole, surmounted by a small flat circular button to which the wire can be attached. When wind is supplied to this valve-actuating motor (or to the membrane), the pneumatic action is said to be on the "pressure" or "supply" system.

When the key is a long distance away from the sound-board, as, for instance, when the console is detached, very long pneumatic tubes have to be used. Now the longer the tube, the greater the friction caused by the pressure-wind travelling through it. Consequently by the time the wind has reached the other end of a tube which is more than ten feet long its pressure is considerably reduced and may be unable to inflate the auxiliary motor or membrane with sufficient rapidity. In such a case, if the key were tapped twice in quick succession, the motor would only fill up once instead of twice as it should do, and this means that the pipe on the sound-board would speak once only instead of twice. There are three possible remedies for this grave defect. The first is to increase the wind-pressure supplied to the tube to the degree required to work the motor satisfactorily. The second is to reduce the size of the auxiliary motor to suit the given wind-pressure. If, however, the motor is made too small it will not be powerful enough to move the disc-valve against the pressure-wind in the wind-chest, unless the disc-valve also be reduced in size. This, again, will mean reducing the exhaust and supply hole for the main motor, causing the latter to move too sluggishly. So we are driven to the employment of a *third* motor, known as the "secondary" motor, which is controlled by the disc-valve and itself controls a second disc-valve (see Fig. 17, which is an illustration of Binns' patent tubular-pneumatic action). Here the disc-valve *a* on being raised enables the secondary motor *b* to exhaust, thus raising the lug *c* attached to its tail or hinged end. The second disc-valve *d* (attached to the lug) now rises and

enables the main motor *e* to exhaust. The disc-valve *a* is half the size of the disc-valve *d*; the secondary motor *b* is a third of the size of the main motor *e*; and if an auxiliary motor were substituted for the membrane it would be half the size of the secondary motor. Both the main and the secondary motors are placed on the bottom-board of the wind-chest.

The third remedy is to introduce a "relay." A glance at Fig. 18 will acquaint the reader with the design of a relay machine. When the pneumatic tube has travelled half the distance required it enters the supply hole at *a*, thus inflating the small motor *b*; this raises the double disc-valve *c* and enables the wind to pass from the pressure-chamber D (which is supplied by a trunk from the main reservoir or main trunk) through the channel *e* into the pneumatic tube *f*, which supplies wind to the pressure motor under the sound-board. The relay therefore gives fresh impetus to the supply of wind in the tube, and is nearly as effective as shortening the tubing by one-half. When the tubing is more than thirty feet in length, it will be seen that all the three methods above described of counteracting the effect of friction in the tubes can be used conjointly, and the diameter of the tubing should not be less than $\frac{7}{16}$ in. internally. In very long-distance actions, more than one relay has been employed, but a point may be reached at which it is impossible to secure quick repetition of the movements, and then it is that recourse has to be had to electricity. Another type of pneumatic sound-board pressure action is shown in Fig. 19, which illustrates one form [1] of the Vincent Willis tubular pneumatic lever of 1899. Here the whole of the mechanism is placed *outside* the sound-board chest, possessing its own pressure-chamber, the main motor being made to inflate downwards.

When the *exhaust* system of tubular pneumatics is applied, the subsidiary motors are placed *inside* a separate chest (called an auxiliary machine) connected with the wind-chest. Fig. 20 gives a well-known example of the type, in which first the auxiliary motor *a*, then the secondary motor *b*, and finally the primary or main motor *c* are exhausted in turn. The auxiliary motor *a* (normally kept supplied with wind from the pressure-chamber through a small hole) is exhausted through the pneumatic tube *d*, which is kept closed at the

[1] The inventor devised several varieties embodying the same idea.

console end while the key is in its normal position; the depression of the key allows the wind to escape from the motor through the tube into outside atmosphere. It is not necessary to make every motor exhaust; the secondary motor can be arranged to be inflated, the disc-valve being attached to its tail end. Also the main motor can be placed *outside* the auxiliary machine and inflated downwards. In other words, in both pressure and exhaust pneumatics, the primary (or main) and secondary motor can be made to exhaust or to be inflated according to the caprice of the designer, and the primary motor can be placed either inside or outside the pressure-chamber (be the latter the sound-board chest or the auxiliary machine); but in the pressure system the small auxiliary motor must be outside and inflated by the pneumatic tube, while in the exhaust system the small auxiliary motor must be inside and deflated through the pneumatic tube.

We must now turn our attention to the console end and see how the wind is exhausted through the pneumatic tube in the case of the exhaust action, and how it is supplied to the tube in the case of pressure action. The releasing of wind from a tube by opening one end of it is a very simple matter, consequently the exhaust key-touch machine at the console is far less complicated in its structure than the pressure touch-box. Fig. 21 gives the movement of a single key, which on being depressed raises its tail end against the jack-pallet *a*, lifting the pallet up and off the tube-hole *c*, and thus allowing the pressure-wind from the auxiliary motor at the sound-board end to exhaust into outside atmosphere. The release of the key brings the pallet down on to the exhaust hole *c* and makes it air-tight. It is quite easy to arrange for several tubes to be exhausted simultaneously by the movement of the jack-pallet, as is shown in Fig. 22, which gives the end section of an exhaust pedal key-touch machine. Here the pedal key, having a downward movement, depresses the pallet controlling the tubes above.

In Fig. 21 the screw wire *d* determines the *depth* of the movement of the key at the console, which should be $\frac{5}{16}$ in. The pallet spring *b* determines the *weight* of the touch, which should be from three to five ounces.

The key-touch arrangements for supplying pressure-wind to the tube are more complicated. Fig. 23 gives a drawing of a pressure touch-box showing the action of one key. The old-fashioned tracker

action and chest is here reproduced in miniature. The chamber A is filled with pressure-wind from the main trunk or reservoir of the organ. On depressing the key, the back end of the backfall pulls down the pallet P, thus admitting pressure-wind from chamber A to chamber B above. At the same time the circular disc-valve D is closed down (being attached to the surface of the pallet P) over the exhaust hole E, rendering the chamber B air-tight. The wind has therefore no outlet but through the tubes C C C which supply the sound-board motors.[1]

On releasing the key, the pallet P is closed, opening the disc-valve D, thus cutting off the wind from the pressure-chamber A and allowing the wind in the tubes C C C to exhaust through the hole E into outside atmosphere. The pallet P is controlled by a spring, the tension of which determines the weight of the key. The wind should not be able to travel through the tubes with sufficient force to inflate the sound-board motor until the disc-valve D has entirely stopped the exhaust-hole E; consequently the key should be depressible at a distance of $\frac{1}{8}$ in. before sounding the note. This "false touch" is a very important factor in key repetition, for the player ought to be able to obtain all the repetition he wants without being compelled to remove his finger from the key. In fact, the great desideratum in pressure pneumatics is the provision of a *false touch* in connection with the exhaust on the touch-box.

Some pressure touch-boxes are constructed without this exhaust (mainly for economical reasons, as the designer is then enabled to dispense with non-return valves in the coupling machine, and can also arrange for all the manual touch-boxes to be built in one block), but it is impossible to deflate the auxiliary motor rapidly enough on releasing the key without devising some means of egress for the pressure-wind in the supply-tube at its console end, *i.e.* at the same end as that in which it receives its supply.

Another form of false touch exhaust is shown in Fig. 24, and is superior in design to that already described, but more costly in its construction and more troublesome to regulate during its installation. The key tracker A pulls down the floating lever B and at the same

[1] Three tubes are given in the drawing instead of one, because as a rule extra tubes are required to supply coupler action, but this is a subject which will be dealt with in the next chapter.

time the exhaust-valve E, which is held up normally by the spring F. This movement achieves two things simultaneously. It closes up the exhaust-hole K and enables the valve to act as a fulcrum to the floating lever B, which now becomes a backfall lever. The downward travel of the valve is regulated to be exactly $\frac{1}{8}$ in., and this gives the required false touch. Further depression of the key next pushes open the pallet H to the extent of $\frac{3}{16}$ in. by raising the tail end of the backfall lever B, and wind immediately rushes out of the chamber D (continuously supplied with pressure-wind by a trunk) into the tubes G G G.

The moment the key is released, the spring F pulls off the exhaust-valve, providing an instantaneous exhaust from the chamber C, even *before* the supply-pallet H has time to close down.

A perfect key repetition equal to that obtainable from direct mechanical action is thus ensured. There is one other method of exhausting the pneumatic tube at the console end, and that is by the employment of attenuated air. The tube is connected with a continuous chamber from which the air is exhausted by the operation of a vacuum bellows. The same operation can be performed by a human being who places the end of the tube between his lips and sucks out the air. If the tube is already releasing pressure-wind (supplied at the other end), the sucking operation increases the momentum of the escaping wind, and the motor at the other end collapses with lightning rapidity. This is technically known to organ builders as the "forced exhaust" system, and Fig. 25 gives an illustration of a very simple form of it introduced in 1869 by Pulbrook, and represents the earliest example of tubular-pneumatic key action.

The key-touch machine consists of a suction box, to which the pneumatic tubes are connected, and a pallet in the box controls the opening of the tubes to vacuum, the pallet being controlled by the key. The motor is placed on the floor of the wind-chest, and forcibly deflated, thus pulling down the sound-board pallet. The spring returns the pallet home on release of the key which closes the vacuum chamber. Better still is the application of vacuum and pressure combined, as shown in Fig. 26. Here the depression of the key forcibly exhausts the pallet-motor as in Fig. 25, but instead of relying on the spring to return the pallet, the release of the key admits pressure-wind to the motor and ensures a smart return. In other words, the motor is

normally inflated with pressure-wind from the touch-box, until the depression of the key forcibly deflates it. Another method of using the vacuum exhaust is to substitute it for the natural exhaust-vent shown in Fig. 24, pressure-wind inflating the sound-board auxiliary motor, and vacuum forcibly deflating it.

Of the three systems of tubular-pneumatic action above described, some builders prefer the natural exhaust (see Fig. 20) because it admits of a very simple key-touch machine and coupling arrangement at the console, and, moreover, does not demand a very heavy wind-pressure for its effectual working. On the other hand, the weak point in the system is *the necessity of making a very small supply-hole* (*about* $\frac{1}{32}$ *in.*) *in the auxiliary motor in the pressure-chamber of the auxiliary machine* (see Fig. 20), so that the motor may be constantly inflated when the key is not depressed. This means that even while the motor is being exhausted (by depression of the key) pressure-wind is *still* entering it by this hole, consequently the hole has to be made sufficiently small to prevent its competing with the exhaust action, and yet not so small that it precludes quick re-inflation of the motor on the release of the key. It stands to reason that the difficulty in such a system is to hit the happy medium. But taking all the *pros* and *cons* into careful consideration, the pressure system (with or without vacuum) seems to be the most efficient, even though it may demand a more complicated design.

(4) When more than sixty feet of tubing has to be used, the tubular-pneumatic action begins to present difficulties in the matter of attack and release, and while it is possible to get pneumatics to "work" at a distance of a hundred feet between console and sound-board by means of relays, extra heavy wind-pressure, and vacuum, there can be no doubt that for very long distances the pneumatic action by itself is unequal to the task. Recourse has then to be had to electrical aid, and an electro-magnet is usually substituted for the auxiliary motor of the sound-board action, and excited by a wire contact at the console. The wires are run through a cable, which may be of any length without making the slightest noticeable difference to the repetition of the action.

It is not within the scope of this book to describe the electric action in detail, for such a description will only be wasted on anyone who is not an electrician, and if one versed in electricity happens to be reading

these pages, he will readily perceive how to apply his knowledge to the effectual substitution of contacts for pneumatic key-touches, and of magnets or solenoids for the auxiliary pneumatic motors at the sound-board. He may with advantage study the patents of Vincent Willis, Hope-Jones, Jardine-Metzger, and the present Henry Willis, junior, whose Liverpool Cathedral action shows that he is in no way the mechanical inferior of his predecessors of the famous house.

The electric current was formerly supplied from a battery of dry or wet cells, or from accumulators, a circumstance that has largely tended to discredit electric systems, as organists do not feel called upon to see to their maintenance. Modern practice is to provide a motor generator, or to attach a low voltage dynamo to the spindle of the blowing motor, when such exists. Excellent and reliable installations on the motor generator principle have been erected by Messrs Harrison & Harrison, the pressure being usually about ten volts, and the current about twelve ampères. There still exists, however, the danger which attends the employment of a number of contacts which are often somewhat fragile and require delicate adjustment. If only one contact per key were necessary, there would be little risk of a bad contact, but with the addition of couplers several contacts are required for each key, and this is asking for trouble, especially if the building which contains the organ is situated in a manufacturing town. In any case, the contacts require more constant attention than pneumatic work, and it is not always easy to make provision for this careful nursing. Nevertheless here, as in other matters, the risk of a break-down may be minimised by the employment of first-class materials and workmanship, as may be instanced from the fact that the Hope-Jones action at Balruddery is still as the builder left it nearly twenty-five years ago, that the beautiful Willis electric touches at Canterbury Cathedral are still as satisfactory as when they were first installed, and that the fine Harrison Unit organ, played by Mr Pattman, gives no trouble in any town in which it is used. The reason is that in all three cases cited the contacts are of gold and platinum, and in the case of the Willis organ all the work is of a quality and finish equal to the highest class of watch-making.

B. Having considered the various methods by which the depression of the key at the console admits wind to the pipe on the

sound-board, we must turn our attention to the mechanism affecting the control of the various ranks of pipes; in other words, to the *draw-stop action.*

Fig. 27 shows the ordinary mechanical draw-stop from the console jamb to the sound-board slider. The trundle *a*, which may be made of either wood or iron, and possesses arms B B of the same material, works similarly to a roller. When the draw-stop rod C is drawn towards the player, the trundle *a* is turned slightly to the left; this moves the rear arm *b* round to the left, draws the trace *d* also leftwards and also the bottom end of the lever *e*; the top end thus makes an outward (or rightward) motion and draws out the slider. Pushing in the rod *c* reverses the movement.

There are many forms of pneumatic draw-stop action. In all cases the sound-board slider is drawn out and pushed back by a single or a double motor placed vertically. The double motor may have a movable middle frame or else a fixed middle frame and movable sides. A single motor, however, can be employed quite effectually. A good model (designed by Holt of Walsall) is shown in Fig. 28. The motor C is enclosed in an air-tight chamber D, the trace being connected to the slider through a leather purse. The chamber E is continuously charged with pressure-wind. The exhaust-valve F is held up by the membrane G which is supplied from the pressure-chamber E, while the valve H supplies wind to the motor C through the channel A. On drawing the stop, the exhaust-hole B is closed and wind passes through to the chamber D. This balances the pressure on the membrane G, and the exhaust-valve F drops by its own weight and releases the wind from channel A, and the wind in chamber D forces the motor back. At the console end the movement of the draw-stop rod merely controls a slider which supplies pressure-wind through a tube to the auxiliary motor at the sound-board end. In Fig. 28 an auxiliary motor can be connected to the valve which on being inflated raises it and closes the exhaust-hole B.

Draw-stop motors can be actuated by pressure and vacuum or by natural exhaust and pressure.

The draw-stop action for a sliderless chest is usually worked either by a ventil controlling the admission of wind to the chest or by a slider controlling the admission of wind to the key-touch tubes which supply

the chest motors. The pressure ventil draw-stop box is constructed exactly like the pressure touch-box illustrated in Fig. 23, a large hole being substituted for the tubes there shown through which the sound-board is supplied with pressure-wind. The pallet *a* can be pulled down by direct mechanical action or else by a collapsing main motor on the same principle as that shown in Fig. 16 *a*. The exhaust-hole and valve allow the residuum of wind to escape from the chest to the open air. The best draw-stop action for the pedal organ where sliderless chests are used is that in which each draw-stop moves a slider which controls the admission of wind from the touch-box to the tubes supplying the key action. The action of the slider can be grasped by a glance at Fig. 29, in which the draw-stop is not drawn and the slider-holes consequently do not correspond with the tube-holes.

CHAPTER II

THE CONSOLE

THE Console is that part of the organ at which the performer sits, and consists of the manuals and pedal-board, the draw-stops, combination movements and all the various means of control which are placed by the builder at the organist's disposal to enable him to manipulate the instrument. In short, the console is the "brains" of the organ.

The *keyboards* or claviers manipulated by the hands are called "manuals," the pedal-board (or "pedals") being reserved for the feet. The largest number of manuals controllable by the player is five, but it is never necessary to have more than four. The conventional names for the five manuals are: (1) great, (2) swell, (3) choir; (4) solo, (5) echo. Sometimes they are called Manual I, Manual II, Manual III, Manual IV, Manual V, especially by designers of the unit organ (see Chapter VI.). In England the order of manual claviers counting from the lowest upward is choir, great, swell, solo, echo. On the continent the great is usually the lowest manual. The compass of the manuals is CC (the octave above the lowest pianoforte C) to C^4, namely, five octaves and 61 notes. In early Victorian organs the top note is F, G, or A below C^4. The compass of the pedals is CCC (the lowest pianoforte C) to F (30 notes) or G (32 notes), covering a range of two octaves and a half. The series of C notes on the organ are called by the following names:—

CCCC	32 ft., the lowest organ note.
CCC	16 ft., the lowest pianoforte C.
CC	8 ft., the lowest manual key.
tenor C	4 ft.
middle C	2 ft. (or C^1).
treble C	1 ft. (or C^2).
C in alt	6 in. (or C^3).
top C	3 in. (or C^4).

The *keys* of the manual claviers are made similarly to those of the pianoforte, and are really levers working on centre pins. The pedal keys are depressed at the posterior end and controlled by the tension of a stout spring. Each manual keyboard is set in its own wooden frame which bound the bass and treble end of the manual. The length of the natural or white keys is $5\frac{1}{2}$ in., that of the sharps or black keys $3\frac{1}{2}$ in. The width of the natural is $\frac{7}{8}$ in., that of the sharp $\frac{3}{8}$ in. The sharps are raised $\frac{1}{2}$ in. above the level of the naturals. The distance between the sharps should not be less than $\frac{5}{8}$ in. at the root; some performers prefer $\frac{3}{4}$ in. The width of an octave stretches $6\frac{1}{2}$ in., the total width of the keyboard of 61 notes is 2 ft. $9\frac{1}{2}$ in. In the case of more than one manual, the overlap should not exceed $1\frac{1}{2}$ in., and the distance between the manuals should be from $2\frac{1}{4}$ in. to $2\frac{7}{8}$ in., unless key-stops are used and placed between the manuals, when the distance may be 3 in. The depth of the manual touch should be $\frac{5}{16}$ in., and the weight of the key should be tensioned from 3 to 5 ounces.

The *pedals* are best concave and radiating, and should be placed so that the DD of the pedal-board may be exactly under the middle D of the manuals.[1] The distance from the top of the middle natural key of the pedals to the top of the middle key on the lowest manual is usually 2 ft. $6\frac{1}{2}$ in. The distance from centre to centre of the naturals is $2\frac{1}{2}$ in.; the length of the bottom and top sharps is 7 in., and that of the two middle sharps $5\frac{1}{2}$ in. The height of the sharps above the level of the naturals is $1\frac{1}{4}$ in. The measurements above given are those most generally approved by organists, but it is not possible to standardise them all to suit every performer, and certain modifications may be necessary to provide a comfortable console for an organist possessing an abnormal size of hand.

The *draw-stops* are placed at the sides of the manual claviers on polished wood jambs set at an angle of 45° or even 60° so as to face the player. The stop-knobs consist of a narrow round stem (about $\frac{5}{8}$ in. diameter) surmounted by an ivory-faced knob which is $1\frac{1}{16}$ in. to $1\frac{1}{8}$ in. in diameter. The name of the stop is engraved on the ivory face. Black block type is best as it can be clearly seen. The diameter of the knob is sometimes only 1 in., but it is difficult to find

[1] The modern pedal compass is CCC to G, 32 notes. In the case of a 30-note pedal-board, the "C under C" position is generally adopted.

room for a bold lettering on this size of knob. The distance of the draw of the stop-knob is usually 1½ in. It may be less, 1¼ in. or 1⅛ in., or even 1 in., but it is difficult to detect which stops are out and which are in with too short a draw.

The best disposition for the groups of stops on the two jambs is a moot question. In the majority of organs the great stops are placed on the right jamb, and the swell stops on the left. The other groups are not by any means allocated in accordance with a definite rule. But all will agree that accessibility for the performer and symmetry of appearance are the two desiderata that call for paramount consideration. With regard to the question of accessibility, it has to be remembered that the left hand can be spared for stop changing more readily than the right, and that those stops should be most easily accessible which are not so frequently controlled by pistons and composition pedals. To this category belong the choir organ stops and the couplers; consequently these groups ought presumably to be allocated to the left jamb. As we have already placed the swell stops there, we have three groups to arrange on this side, and if each group of stops be arranged in vertical columns, the order of columns can be from inside to outside: couplers, choir, swell. This leaves us the great, solo and pedal groups to be placed on the right jamb. The solo stops can readily be controlled by pistons, and the pedal stops can be arranged to be brought on in conjunction with the manual combinations, when desired, either by a coupler called "Pedal Stops to Great Pistons," or by adjustable pistons which enable the player to fix his own combinations as he wishes. The solo and pedal can be placed inside, and the great outside. The octave couplers are best grouped with the divisions they affect, and are preferably placed at the top of each division; when so grouped they can be controlled by the pistons. It does not matter where the echo division is placed, for it can be controlled by pistons. As far as possible each jamb should possess an equal number of stops, and the above arrangement of the various groups shows due regard for this desideratum.

Another form of draw-stop is the *key-lever*, which is patronised by certain builders and organists. Where these key-stops are used, they are best placed between the manuals, that is *over* the manual they affect, and in this way each stop can be so placed as to correspond with

the position of a certain manual key or note, so that the organist (and especially the blind organist) may be able to associate this or that stop with this or that key. For instance, the great open diapason No. 1 key-stop can be placed immediately over middle C of the great manual, the No. 2 open can correspond with middle D, the No. 3 open with E, the clarabella with F, and so on. Another advantage claimed for the key-stops is that the closeness of their grouping enables the performer to depress several at a time with ease when combinations of stops are required. Those who dislike this form of stop usually point to the increased distance between the manuals which the interposition of the key-levers necessitate, and also to the confused appearance of so many rows of ivory keys massed together. Where the console is detached and connected with the main organ by electric action, these key-levers are certainly the simplest form of control, especially as only a very small movement is desired for electric contacts. Moreover, the width of the console can be materially reduced by dispensing with the draw-stop jambs. But it is not the author's intention to make any arbitrary declaration in favour of either system.

The *coupler* is a mechanical contrivance whereby more of the organ key-board is brought under the player's control than would be possible with two hands and two feet. Couplers are three in kind—inter-clavier, octave and unison off. The inter-clavier couplers couple the manuals to each other, and the manuals to the pedals; the octave couplers add the octave below or the octave above to the notes played on any given clavier, and are known by the names "octave" or "super-octave" and "sub-octave." The unison off coupler detaches the notes played in any given clavier. Thus if a chord be played on the swell manual, the drawing of the swell unison off coupler produces silence, while if the swell sub-octave or super-octave coupler be drawn along with the unison off coupler, the chord will be transferred an octave lower or higher as the case may be. Inter-clavier octave couplers are introduced by some builders, such as "swell octave to great" and "swell sub to great"; the unison off effect is then brought into operation by merely omitting to draw the swell to great coupler (*i.e.* the unison inter-clavier coupler), and playing on the great manual. These couplers add enormously to the organist's resources, and form the basis of the unit system of organ design (see Chapter VI., p. 101).

The pneumatic coupling mechanism is always best placed "in the console," that is, just behind the key touch-boxes, which are themselves placed at the back of the music-desk. Their description therefore belongs to this chapter, and a few words on the subject of their design will not be out of place.

The "mechanical" coupler usually consists of a set of backfall levers attached at the near end to the tail end of the keys of the one manual and at the further end made by the drawing of the stop to engage on to the trackers of the other manual. The octave coupler works similarly except that the backfalls are placed diagonally so that the further end may pull down the tracker of the octave key. This mechanism naturally increases the weight of the key touch and is fast growing obsolete. Couplers must either be pneumatic or electric in principle.

There are two distinct pressure pneumatic coupling systems. Both are worked in connection with the pressure touch-box. The latter supplies pressure-wind to pneumatic tubes which in their turn supply wind to the sound-board auxiliary motors (see Chapter I., p. 25). The coupling machine is placed *between* the touch-box and the sound-board action, but quite close to the touch-box. It is, strictly speaking, part of the "inside" of the console. For each key there is a set of tubes taken from the touch-box, one tube for each coupler affecting the clavier. Take, for instance, the swell manual. If we wish to provide this with "swell octave," "swell sub-octave" and "swell unison off," three tubes are taken from the swell touch-box. These tubes are fixed into a horizontal board bored with tube-holes, called the "distributor," and behind this board sliders are placed bored with holes made in the case of the octave couplers to correspond with the front-board holes when the coupler stop is drawn, the reverse movement being arranged for the unison off coupler. At the back of the sliders another thicker board, called the "mixer," is placed, containing vertical groove-channels connecting the front-board and slider holes with a *single* set of tubes (one for each note) taken from it at the further end. Thus if the note middle C on the swell be depressed, the pressure-wind passes from the touch-box to each of the tubes taken from it. The "unison off" tube supplies the middle C sound-board auxiliary motor unless the "unison off" coupler be drawn, when the slider in the dis-

tributor intercepts the wind. The other two tubes are fixed to the tenor and treble C holes of the distributor respectively, and are both a *cul-de-sac* until the sub-octave and octave couplers are drawn, when the wind is enabled to communicate with the corresponding groove-channels of the mixer, and passing through the unison tubes to inflate the sound-board tenor and treble C motors. Fig. 30 gives a sketch of this coupling machine as it affects the operation of a single key. Inter-clavier couplers can be worked in the same way. In the case of the "swell to great" coupler, for instance, the tube is taken from the great touch-box and connected to the swell distributor, where, by the drawing of the slider, the wind is admitted through the mixer to the swell unison tube.

As has already been explained in Chapter I., p. 25, the key repetition is seriously endangered unless exhaust-valves are provided at the touch-box. But this means that the wind supplied to any one of the coupler tubes will run back to the touch-box through one of the other tubes, and escape through the exhaust-hole into outside air instead of going to the sound-board motor, unless non-return (or "back-pressure") valves are placed in the mixer groove. Leather flap valves, acting in this capacity, are shown in Fig. 30, one being fitted to each tube-hole.

A different form of coupling machine, more costly and complex in design, is shown in Fig. 31. Here the depression of the key inflates the motor M, and reverses the double disc-valve C C, thus releasing pressure-wind from the chamber D through the channel E to the tube F. At the same time the non-return valve V (best made of papier-maché covered with soft kid) is forced against the opening of the tube G and effectually closes it. Release of the key reverses the action.

Now suppose this to be arranged for a swell to choir coupler, then tube A will be taken from the choir touch-box, tube F will go to the swell sound-board auxiliary motor, and tube G will be taken from the swell touch-box. When the *swell* key is depressed, wind passes from the swell touch-box into tube G and through tube F to the swell auxiliary motor. If the non-return valve V were not provided, the wind would run through the channel E and out into the open air, and therefore could not inflate the swell auxiliary motor. As it

is, the valve V is forced back against the opening of the channel E and closes it. When the *choir* key is depressed, the wind stored in the pressure-chamber D is enabled to pass through the channel E to the tube F and to inflate the swell auxiliary motor, so that depressing the *choir* key brings the *swell* action into play. If, again, the valve V were absent, the wind would escape through the tube G into the swell touch-box and out through the exhaust-hole there, and thus would be unable to inflate the swell motor through tube F. The coupler is put on and off by means of a ventil or pallet, which controls the admission of wind to the chamber D.

The pedal unison couplers are usually arranged "mechanically" by backfall and tracker connections. The octave couplers can be designed in the same way as for the manuals.

Various accessories are provided by the console-designer to facilitate the control of the draw-stops during the performance of a piece. In the old-fashioned tracker organ, composition lever pedals were supplied with the object of moving a given selection of stop-knobs in and out. In the pneumatic organ these are replaced by pistons, which are little ivory studs, slightly concave at the face, placed on the key-slips between the manuals, and underneath the manual affected, so that the organist's *thumb* can reach them with ease. Piston knobs or pedal levers are also provided on the pedal for the toe to press, and usually these pedal pistons duplicate the thumb pistons, with the idea that when the player cannot spare a thumb he can spare a toe. The modern system of making the pistons adjustable—that is, enabling the player to arrange *any* combination of stops to be thrown out by *any* piston before he starts to play (instead of having a *fixed* set of combinations which he is bound to use whether he likes them or not)—has revolutionised the stop-control of the organ.

The action of the mechanical composition pedal is quite simple. Small wooden blocks are fixed to the draw-rods, and a light steel frame or "fan" is centred to engage upon these blocks. These fans are arranged in pairs, each acting in the opposite direction, in the same manner as the closing and opening of the covers of a book. While one of the fans brings out certain stops, the other fan draws in certain other stops.

In the case of pneumatic pistons, single fans are worked backwards

and forwards by large motors either exhausted or inflated by the operation of the pistons, or else double-acting motors replace the fans and are exhausted or inflated in the same way. The pistons are made adjustable by means of "locking knobs." The player first draws the combination of stops he requires on any given manual, and then pulls out the corresponding locking knob. This done, the combination selected is always brought out by the piston thus "locked," until another combination is drawn and "locked." What the locking-knob does is to engage each stop drawn on to the fan, while all stops not drawn are not affected by the fan.

As a rule the pistons are arranged to draw out the various combinations in gradation of power, No. 1 piston giving the softest combination, the last piston giving the full power of the manual affected. The thumb pistons are placed in a horizontal row, and work from left to right. All may be adjustable, but the last one on the extreme right may be fixed to give full power. When this is so, it is a mistake to attach *all* the stops of the manual affected to the fan, only those being required which produce the desired effect. All the softer stops should be excluded from this piston—in fact, all stops which would be drowned by the louder ones. Five adjustable pistons to each manual will provide the organist with practically all he wants, even for the control of a large organ; whereas, if the pistons are fixed, he will require several more in proportion to the number of combinations obtainable, and he will then be handicapped by having too many pistons to manage. The pedal stops should be capable of being added to the manual combinations if desired, but it is a bad thing to fix them to the manual pistons so that they have always to be used with them. Such an arrangement can be controlled by a manual and pedal combinations coupler, which may be labelled "pedal to great pistons" or "pedal to swell pistons," as the case may be. The adjustable pistons can be made to control the pedal stops together with the great stops, in which case the great and pedal draw-knobs must be placed on the same jamb, and the adjustable pistons may also control the couplers, especially the octave and unison off couplers. Again, some builders arrange a set of pedal levers to control the pedal stops only, and make them available in conjunction with the manual pistons by the manual and pedal combinations couplers above referred to. Or again, there is the

" suitable bass " attachment which when drawn supplies an appropriate pedal bass to every manual combination that happens to be selected by the player. In any case, what the organist requires is an effectual means of controlling his manual and pedal combinations without being tied down to a definitely fixed selection of stops when moving the pistons.

There are certain stops which demand individual control. Such are the great to pedal, the swell to great, the choir or solo to great couplers, the tremulants and certain solo stops. For the above-mentioned couplers, reversible pistons are best as a means of control. When pushed the first time the reversible piston brings the coupler into operation ; the next push takes the coupler off. For the great to pedal coupler, an " on and off " or " poppet " pedal is often provided, which may be mechanical or pneumatic. The most modern form of this coupler is a pedal lever which when depressed brings the coupler on, and when depressed again takes it off. The tremulants may be controlled either by draw-stop, or by a piston placed on the key-cheek, or else by a pedal lever. As the tremulant is a special effect, the actual means adopted to control it is not a matter of vital importance. Solo stops are best controlled by reversible thumb pistons placed on the key-slip under the solo manual.

We come now to the control of the swell boxes. References to the swell box will be found in the chapters dealing with the tonal department of the organ. As every organist knows, certain stops of pipes in the organ are encased in a tightly panelled box fitted with louvres or shutters which are controlled by a pedal at the console. The opening and closing of the shutters create a *crescendo* and *diminuendo* effect on the pipes enclosed in the box. It may be here mentioned (though it has nothing to do with the console arrangements) that the walls of the swell box should be thick, not less than 3 in., and lined with either cement or tin so as to cause them to act as reflectors, the object being to focus the sound-waves on to the shutters. The same purpose is also served by making the roof of the box slant upwards from the back. The shutters also should be placed as high up as possible if horizontal in form ; if vertical they should extend to the top of the box front. The shutters and the panels must all fit perfectly tight if any proper *crescendo* effect is to be obtained. Excellent swell boxes

are also constructed of bricks and mortar and plastered inside with cement.

Organists and builders differ in their opinion as to the best methods of controlling the shutters from the console. When the choir and the solo organs as well as the swell organ are enclosed, three sets of shutters have to be controlled, and it is necessary to be able to control them simultaneously. This means three pedal levers placed in a row and simultaneously accessible to one foot. If the levers are placed over the centre of the pedal board, they can be operated by either right or left foot as desired ; if placed at one side, they can only be worked by *one* of the feet. Then again, the type of lever best suited to the purpose is a vexed question. The old-fashioned pedal lever is placed on the right-hand side of the pedal board, and has a " trigger " movement. It is kept down (leaving the shutters open) by a notched stick, which catches it at a certain point. When released from the catch, the lever flies back to its normal position. More than one notch can be cut into the catch so as to arrest the lever at certain intervals, but the organist generally finds it difficult to shut the box smartly, because this ratchet arrangement is apt to interfere with the free return movement of the lever. The more modern lever is a flat piece of wood balanced on a centre pin, and may be left fully open or closed or in any intermediate position when the player's foot is released. This presents great advantages over the old trigger pedal, although there are still some organists who cling to the latter type. The lever may be connected with the swell shutters " mechanically " by a series of rods and squares, and if possible direct control is the best. But in the case of a detached console, recourse must be had to either pneumatic or electro-pneumatic assistance. The usual form of pneumatic control is by means of a set of large motors connected to the shutters, one for each shutter, which are inflated one by one on the pedal lever being depressed, thus opening the shutters gradually. Or else a large double-motor may be attached to the shutters and gradually inflated and deflated to open and close the shutters, the supply of wind to the motor being controlled by the lever pedal.

The console may be constructed to form an integral part of the organ, or else it may be separated from the main organ and placed in some other part of the church ; when this is done it is usually placed

close to the choir stalls. The "detached console" opens up many problems to the organ-builder, and obviously increases the cost of an organ considerably. The actual advantage to be gained from it is not so axiomatic as people imagine, for when the organist is removed from the main organ he is certainly able to hear the actual effects he is producing, but, on the other hand, if he sits too close to his choristers, he will experience some difficulty in hearing his accompaniment through the voices. If the organist is seated at a great distance from the choir, he is apt to find that his accompaniment from *his* standpoint is dominating the singers so that it is difficult to "follow the service." Moreover, the sound-waves of the organ and of the choir do not synchronise, and he has to play in advance of the singers. These considerations lead one to the conclusion that the ideal position for the organist is at an equal distance between the pipes of the organ and the choir, or at any rate at some point where the organ and the choir can be heard to equal advantage. When the organ and choir are placed together in a gallery, this *desideratum* can be consummated; but if the choir are in the chancel the organ should be as near to the choir stalls as can be arranged in accordance with the architectural design of the church, either on the chancel screen or under the north or south chancel arches, or else divided north and south. When these positions are chosen, the detached console does not as a rule become a necessity, for every organist who is "worth his salt" is able to acclimatise himself to any reasonable position and to master its peculiar difficulties.

In nearly ninety-nine cases out of a hundred the detached console could have been avoided if the architect of the church had provided adequate accommodation for the organ; but when the only available space is a small tribune or chamber, or when the organ has to be bracketed on to a wall, there is no room left for the console, which has perforce to be squeezed in wherever a small piece of floor-space can be found. Such conditions ought not to exist, and it is to be hoped that church architects of the future will spare a passing thought to the convenient accommodation of the church's instrument, and so make it possible for the money to be spent entirely on the artistic design of the organ instead of being wasted on heroic attempts to surmount problems arising out of the omissions or mistakes of other people.

CHAPTER III

THE SOUND-PRODUCING PARTS

THE organ as a *musical* instrument may be regarded as a collection of speaking pipes, supplied with wind and controlled at the keys by the player. It is the construction of these pipes that we have now to consider. There are three distinct forms of organ pipe, namely:

1. Flue-pipes.
2. Reeds.
3. Diaphones.

Their differences may be readily grasped by the student who troubles to study the drawings in Figs. 32-36.

Fig. 32 gives the principal sections of a metal flue-pipe with (*a*) the modern languid, (*b*) the early English languid, (*c*) the inverted languid.

Fig. 33 gives the parts of a wooden flue-pipe with (*a*) the square block, (*b*) the sloping and bevelled block, (*c*) the sunk block and an inverted upper lip.

Fig. 35 illustrates the striking reed-pipe. The "free" reed, in which the tongue, instead of beating against the shallot, vibrates freely in and out of the orifice of the shallot, is not used by modern builders, unless for some special reason the organist desires to import harmonium or American organ effects into his instrument. The chief argument against their introduction is that they retain their pitch in all temperatures and are consequently only in tune with the rest of the pipes of the organ when the temperature of the building is the same as it was when the organ was last tuned.

Fig. 36 gives two forms of diaphone. The first form shows a vibrating motor which sends puffs of wind into a resonator at regular intervals, acting similarly to a tremulant. The second form substitutes a vibrating circular valve for the motor, controlled by a spring.

The diaphone has at present hardly passed out of its experimental stage, although introduced by Robert Hope-Jones in a practical form some twenty years ago. Its use is confined to the pedal organ, to which it is capable of adding immense depth and volume of tone.

The rest of this chapter will be devoted to the laws governing the speech and construction of flue and striking reed pipes.

FLUE-WORK

Flue pipes may be classified into four divisions representing those which produce respectively

1. Diapason } tone.
2. Flute }
3. String }
4. Echoes or miniatures of the first three.

1. THE DIAPASON claims the pre-eminence both historically and from its importance as the essential factor in the tonal design of the organ. An organ without a diapason is not an organ at all; consequently the diapason may very properly be called the "foundation tone" of the organ, and as such deserves more attention than is generally given to it. Let us notice four kinds of diapason.

(*a*) *The Early English Diapason*, so named by the author in his book, "Studies in Organ Tone," is represented by numerous examples still to be found in this country in old organs, by Father Smith, Renatus Harris, Green, England, Knight (of Chichester), Snetzler, Avery, Bridge, Byfield, Jordan, Griffin, Gray, and others.

Although it must be admitted that the standard of excellence varies somewhat in these old examples, generally speaking they all possess a charm of tone which is peculiar to the type. One may best describe the tone as one of old-world peacefulness, a quality which is only obtainable from pipes of special construction standing on a light wind-pressure. The author has reproduced the type in a number of organs at the special request of organists and clergy. The secret lies in the form of languid employed, which is shown in Fig. 32 *b*.

It will be seen that the languid is *thinner* than the modern one (about three-quarters the thickness), that the bevel is more obtuse-angled (30° from the vertical at most),[1] and that the flatting of the lower lip of the pipe is vertical instead of being curved in towards the mouth ("dubbed"). The tone is smooth, round and velvety, the speech being perfectly natural and unforced. "Quality before power" must be the ruling motto adopted by the voicer of this type of diapason. The scale varies from $2\frac{1}{2}$ in. to $3\frac{1}{2}$ in. at tenor C (4 ft. pipe), the half measure falling on the 16th pipe throughout the compass. The mouth may be $\frac{2}{9}$ or $\frac{1}{4}$ circumference in width, and cut up $\frac{1}{3}$ of its width. Ears are not required above middle F. The wind-pressure should not exceed $3\frac{3}{4}$ in., and a lower pressure is desirable, such as $2\frac{1}{2}$ in. or 3 in.

(*b*) *The Schulze Diapason* was introduced into this country in 1851, when the firm of J. F. Schulze & Sons, of Paulinzelle, sent a small two-manual instrument to the Great Exhibition. The attention it attracted led to this firm obtaining a number of orders for larger organs in the north of England, the most notable of which are those at Doncaster, Armley, Tyne Dock and Hindley. The organs at S. Bartholomew's, Armley, and S. Peter's, Hindley (Wigan), remain to this day the noble monuments of the master-voicer, Edmund Schulze, who bequeathed his best work to this country and mightily influenced our northern English builders as well as the late Thomas C. Lewis. There are still some who are apt to think that Schulze's voicing has been overrated; but the fact remains that for general effectiveness the flue-work of the two organs above-mentioned can hold its own with that produced by any other builder, while in some points the Hindley masterpiece is still *facile princeps*.

To turn, however, to the Schulze diapason. The tone is brighter and more vigorous and assertive than that of its early English brother. The earlier examples (*e.g.* those in the Exhibition organ and at Doncaster) were less striking than those at Armley and Hindley, the latter organ containing the most *beautiful* of them all; but at S. Mary's, Tyne Dock, Schulze showed what he could do in the production of power and majesty of tone when it was required for a special purpose. It is not fair, however, to judge his work by the effectiveness of a single

[1] Father Smith's languids were bevelled at 15°, Green's at 30°, the latter being transitional between ancient and modern.

stop, for Schulze was a great tonal architect, and the real glory of his organs consists in the magnificent *ensemble* of his full great flue-work from 16 ft. up to mixtures, the whole of which was treated on the same lines as he treated his single 8 ft. diapasons. The Tyne Dock organ is an exceptional instance, as the proportion of power is not distributed equally among the various pitches, Schulze having followed the example of his English contemporaries in assigning chief prominence to the 8 ft. stop. In Germany the 16 ft., or "sub-principal," constituted the basis of the tonal structure, and Schulze followed this principle in his Doncaster and Armley organs. When we speak, therefore, of the Schulze diapason, we ought always to think of it in terms of the complete edifice of which it is an integral part. The pipe is fitted with the modern acute-bevelled languid shown in Fig. 32 *a*. The mouth is never less than $\frac{1}{4}$ circumference in width, and usually $\frac{2}{7}$, with a correspondingly low cut up ($\frac{1}{5}$ of the diameter of the pipe or $\frac{1}{4}$ the width of the mouth). The full tone is obtained from the pipe consistently with correct speech. Schulze did not employ anything higher than $3\frac{3}{4}$ in. pressure of wind for his diapason chorus, and usually less; but his sound-boards were spacious and generously supplied with wind, and, with the large bores made in the feet of the pipes, a good flush of wind was assured. The scales adopted by Schulze for his various diapasons may be gathered from the following list of examples:

Example.	Scale at Ten. C.	Scale at Mid C.
Tyne Dock, No. 1 (Great) .	$3\frac{3}{4}$ in.	$2\frac{1}{4}$ in.
Leeds Parish Church, No. 1 (now No. 2 Great) . . .		
Armley, Charterhouse and Tyne Dock No. 2 . . .	$3\frac{1}{2}$ in.	$2\frac{1}{8}$ in.
Hindley No. 1 (Great) . .	$3\frac{1}{4}$ in.	2 in.
,, Swell	$3\frac{1}{8}$ in.	$1\frac{7}{8}$ in.
,, No. 2 (Great) . .	$2\frac{7}{8}$ in.	$1\frac{5}{8}$ in.

Many builders have attempted to reproduce Edmund Schulze's diapasons with more or less success; but as a rule their imitative efforts have been confined to the 8 ft. stop with the idea of grafting it on to their own pet flue chorus. This inevitably led to a modification of the

wide mouth, which was reduced from $\frac{2}{7}$ to $\frac{1}{4}$, as being more amenable to treatment. It would have been more profitable to the organ-building art had Schulze's *upper work* been faithfully reproduced, especially the octave ranks (principal, fifteenth and twenty-second), but this point will receive attention in its right place. As it is, the many bad examples of so-called reproductions of the Schulze diapason perpetrated in the Victorian era have paved the way for a peculiarly English type of diapason, which may not inaptly be called

(*c*) *The Modern Foundational Diapason.*—The desire for abundance of unisonal foundation seems to be characteristic of the genius of the British race, for in Germany and France even the largest organs possess only a modicum of flue foundation. Be this as it may, the modern English organist is not content to restrict his tonal diet to a feast upon the beauties of either the early English or the Schulze diapason, but demands to be served with something more solid. He complains that the early English type is inadequate to cope with the heavy pressure reeds of the modern organ, and that the Schulze type is more brilliant than foundational. What he asks is that the foundation and refinement of the older examples may be magnified to the power of the Schulze diapason, and this desideratum has taxed the ingenuity of the greatest of our voicers, with the result that a number of different species of foundational diapason have been evolved by different firms. It will suffice to mention three of these.

(1) A large scaled pipe, say 4 in. to $4\frac{1}{2}$ in. diameter at tenor C, with narrow mouth cut up high (say $\frac{1}{5}$ circumference, cut up $\frac{2}{7}$ diameter), with large ears, wide flue and convex upper lip, standing on at least 4 in. pressure of wind.

(2) A medium scaled pipe (say, $3\frac{1}{2}$ in. at tenor C) with a $\frac{2}{9}$ width of mouth, cut up high (say $\frac{2}{7}$ diameter) and having the upper lip coated with thin leather, standing on heavy wind (from 5 in. to 10 in. or more). This is often called a "phonon."

(3) A medium scaled pipe, not exceeding 4 in. at tenor C for the most powerful type, with a $\frac{1}{4}$ width of mouth, cut up $\frac{1}{3}$ of its width (or $\frac{1}{4}$ diameter), with either (*a*) a reinforced upper lip or (*b*) the upper lip burnished on the anterior and posterior edges. The wind-pressure not to exceed $4\frac{1}{2}$ in. for normal cases, and the boring at the foot to be large.

Of these the author has a distinct preference for No. 3, the practice of burnishing the upper lip (especially its posterior edge) having been introduced by him in the year 1900, with the object of eliminating the higher dissonant upper partials without unduly curbing the first two (octave and twelfth).

No. 1 lacks robustness and definition, and in No. 2 one misses the essential "ring" or buoyancy of the true diapason. Moreover, it is difficult to build up a complete flue chorus on either of these types, for the upper work (principal, fifteenth, twenty-second and mutations) must either be restrained to the point of negligibility, or else, if properly developed, it will create a hiatus by "standing away" from the unisonal foundation. These objections do not apply to No. 3, while ample foundation can be secured consistently with fine pure tone.

(*d*) *The String Diapason.*—Under this category is placed a type of smaller diapason in which the upper partials are legitimately developed without converting it into an actual string stop. There are four varieties of the genus.

The *Violin Diapason* or *Geigen Principal* was introduced into this country by Schulze, and is a small scaled Schulze diapason, with a wide, low mouth fitted with a beard. The scale is usually $2\frac{5}{8}$ in. at tenor C. The English violin diapason is usually a slotted pipe with a narrow mouth ($\frac{1}{5}$ or $\frac{2}{9}$), the scale being sufficiently large to enable the voicer to dispense with the beard. The best (and certainly the most rational) method of treatment would be to employ a $2\frac{1}{4}$ in. scale slotted pipe at tenor C (4 ft.) with a $\frac{2}{9}$ width of mouth fitted with a wooden roller, working this scale up to $1\frac{1}{2}$ in. at mid C (2 ft.), at which point the pipes should no longer be slotted nor rollered, but the width of mouth increased to $\frac{1}{4}$, with metal beards. These latter should cease at treble C (1 ft.), and the mouth should be increased to $\frac{2}{7}$, with a scale of $\frac{15}{16}$ in.

The *Salicional Diapason*, usually labelled "salicional" or occasionally "viola," is a small-scaled diapason, unslotted, with a narrow, low mouth, possessing less fire than the geigen. It represents the feminine side of diapason tone, being light and "velvety," the modicum of string tone imparted to it affording a delightful contrast to the other main types of diapason. The author always burnishes the upper lip

of this pipe in order to ensure a soft velvety quality, at the same time leaving the anterior edge bevelled.

The *Gemshorn* (or *Spitzflute*) has a conical pipe, the diameter at the top being about a third of that at the mouth; this special shape appears to favour the development of the fifth and seventh partials (tierce and septime). It was very popular with Victorian builders, but is fast becoming obsolete. Its *timbre*, however, is peculiar to its species, and possesses a beauty all its own.

The construction and treatment of the bass pipes (CCC 16 ft. to BB=24 notes) of the diapason must now claim our attention.

Whatever type of diapason be employed, the bass portion should always be voiced to give weight and fullness of tone, avoiding stringiness on the one hand and flutiness on the other. A certain amount of "bite" is desirable in the 16 ft. octave, but the 8 ft. octave should be mainly foundational. At the outset the voicer has to decide what *material* he will use for his pipes. Plain metal (to say nothing of spotted metal, which was much employed by the late T. C. Lewis) is very costly and also very heavy, and has largely been superseded by zinc, which is light and durable and also cheaper. Opinions vary as to the merits of this latter metal, and the author has never been able to regard it as ideal, but there is no doubt that thick hard-rolled zinc pipes of large scale, fitted with plain metal lips, are capable of yielding a good weighty tone. Messrs Norman & Beard use the inverted languid (see Fig. 32 *c*) for pipes in the 8 ft. octave as far up as tenor F with good results.

Schulze was very partial to wood for all his basses, and in the use of this material he has had many followers, the most notable being Messrs J. J. Binns, Abbott & Smith, Jardine, Bishop, Brindley & Foster, J. W. Whiteley, and Thomas Pendlebury, the latter voicer having introduced certain important modifications. The author can unhesitatingly recommend the adoption of wood for diapason basses, for as good a tone as anyone could wish for can be produced from pipes of this material. Four sketches of a wood diapason pipe are given in Figs. 33 *b* and 34 *a*, *b*, *c*. A close study of these will give the reader all the information he needs as to their construction.

Schulze seemed to prefer the square pipe, but a rectangular shape gives less trouble to voice.

The following table of scales may be of use to the student :

16 ft. CCC.	8 ft. CC.	Tenor C (metal).
$8\frac{3}{4}$ in. × $7\frac{1}{2}$ in.	$5\frac{5}{8}$ in. × $4\frac{3}{4}$ in.	$3\frac{3}{4}$ in.
8 in. × 7 in.	5 in. × $4\frac{3}{8}$ in.	$3\frac{1}{2}$ in.
$7\frac{3}{8}$ in. × $6\frac{1}{4}$ in.	$4\frac{5}{8}$ in. × 4 in.	$3\frac{1}{4}$ in.
7 in. × 6 in.	$4\frac{1}{4}$ in. × $3\frac{1}{2}$ in.	3 in.
$6\frac{3}{4}$ in. × $5\frac{7}{8}$ in.	4 in. × 3 in.	$2\frac{5}{8}$ in.

The wooden portion need not be carried up beyond GG sharp, and the "break" between wood and metal can be rendered quite imperceptible.

Finally, we have to deal with the *upper work* of the diapason chorus, which consists of the octave work (principal, 4 ft. ; fifteenth, 2 ft., and twenty-second, 1 ft.) and mutation work (quint, tierce, septime and their octaves), the combination of octave and mutation ranks being commonly known by the generic name of "mixtures," or "harmonics." The old builders made it a rule to scale and voice these octave pipes as extensions of the unison diapason. More often than not the scale of the principal at mid C, of the fifteenth at tenor C, and of the twenty-second at CC, was exactly the same as that of the open diapason at treble C (*i.e.* the one-foot pipe) ; and Schulze followed the same rule with his diapason chorus. The upper work of the old builders, however, erred on the side of flutiness, while a great many of our modern organists regard Schulze's upper work as too brilliant. The result is that the octave and mutation work of the present-day organ occupies far less prominent a position than it used to. As a matter of fact, Schulze's upper work (and Silbermann's at Dresden) can hold its own with that of any modern builder ; and even if we may think fit to criticise some of the minor details of its treatment, we may learn from it some valuable lessons.

The *principal* 4 ft., or octave diapason, should be more or less a duplicate of the unison diapason, the scale being one pipe smaller, and the upper lip being bevelled. The tone should be bright and *slightly* less powerful than the unison rank.[1] The fifteenth and twenty-second are never so successful as when the scaling is small and a wide

[1] When more than one unison rank is provided, the designer must decide which of these he wishes to extend in the building up of the diapason chorus. As a rule it is the "No. 1 Open" that should be thus extended.

low mouth is employed. Schulze's $\frac{2}{7}$ mouth cut up $\frac{1}{4}$ of its width (or $\frac{1}{5}$ diameter) is a golden rule whose worth the author has proved by practical experiment.

The scale of the one-foot pipe should not exceed $1\frac{1}{16}$ in. nor be less than $\frac{7}{8}$ in. These pipes will stand on any pressure of wind, and can be adjusted to the power of tone required without losing their silvery quality.

Two very common mistakes which are made in the treatment of mixtures are the suppression of the octaves and the undue encouragement of the mutations. What is really required is the octave work of Schulze or Willis and the mutation work of the old builders. In other words, with the principal, fifteenth and twenty-second scaled and voiced on the lines above stated, the twelfth and nineteenth (and seventeenth and flat twenty-first, if used) should be of somewhat larger scale with narrow mouths (say $\frac{1}{5}$ or $\frac{2}{9}$), voiced on the fluty side and subordinated to the octaves. Early English languids could be used with the $\frac{1}{4}$ mouth, but only if the pressure did not exceed 4 in. The same rule applies to the treatment of the sub-mutations, such as the quint and the tenth; but the latter is very little used nowadays except in the upper octaves of the manual. We have next to consider the question of the composition of mixtures. If the higher-pitched ranks of pipes such as the seventeenth, nineteenth, and twenty-second (*i.e. all* ranks above the fifteenth) were to be continued up right through the compass of the organ, the pipes would be too small to be of any use. They must therefore be discontinued at some point in the compass, and must either stop completely short at this point or be superseded by ranks of lower pitch. This is technically called a "break" in the mixture, and the object of the voicer is to disguise these breaks as ingeniously as possible. It has been the custom in the past to employ loud and high-pitched ranks in the bass register of the manual; but the modern ear can no longer tolerate the disagreeable effect that this produces when the manual is coupled to the pedal, and in any case the balance between the bass and treble registers of the manual is upset by this treatment. This is an important point and vitally affects the question of mixture composition, for it actually means that the mixture proper ought not to begin lower than mid C, there being no mutations (and nothing higher than the twenty-second) from CC to mid B. Then again we have to decide whether the tierce (3rd, 10th,

17th) and flat septime (♭ 7th, ♭ 14th, ♭ 21st) should be included in the mutation ranks. Modern opinion is not inclined in their favour, but we must discriminate between two vastly different kinds of mixture—the *ripieno* mixture which is designed to add brilliance and *éclat* to the organ, and the *timbre*-creating mixture, which is an attempt to reproduce artificially the natural overtones. If we eliminate the tierce and septime from the *ripieno* harmonics, there is no reason why we should not still regard them as *timbre*-creating mutations, and one has only to make the acquaintance of the mixture-work of Messrs Harrison & Harrison or of Cavaillé-Coll of Paris, to be convinced of their effectiveness when so treated. We are, however, more concerned with the diapason chorus of the organ, and consequently, with the composition of the *ripieno* mixture. Moreover, this is the mixture which is designed to blend with the reed chorus, and therefore its architectural importance is paramount. Let us suppose that we have to design a diapason chorus extending from 16 ft. to 1 ft., with the requisite mutation work. We start at CC of the manual with

double, 16 ft.
open diapason, 8 ft.
principal, 4 ft.
fifteenth, 2 ft.
twenty-second, 1 ft.

and we carry this right through to the top note with the exception of the twenty-second, which should not be permitted to go higher than f^2 (the 42nd note from CC). It may then "break" into a lower octave, but if it becomes a fifteenth, we have two fifteenths to one principal in the scheme, and this is not only unnecessary but also contrary to the law of proportion; so that either it should become a brilliant principal (more brilliant, that is, than the already existing principal), or else it should be discontinued at this point altogether. At mid C we may introduce the twelfth and nineteenth, so that the complete scheme at this point runs thus:

16 ft., 8 ft., 4 ft., $2\frac{2}{3}$ ft., 2 ft., $1\frac{1}{3}$ ft., and 1 ft.

The twelfth can be carried through without a break as it is below the fifteenth in pitch, but the nineteenth must end its career at C^3 (48

notes from CC) at latest. It is better to break the nineteenth at a different point from the twenty-second, as if more than one rank break simultaneously the change is likely to be noticed, and it does not matter if the mutation rank tops the series for a few notes, especially as it is in any case quietly voiced and kept subordinate to the fifteenth. At C^3 the nineteenth would not become a twelfth for the reason already given in the case of the break of the twenty-second, but it could well become a fifth (or quint, $5\frac{1}{3}$ ft.) voiced on similar lines. The complete scheme can be specified in accordance with the following plan :

CC to C^4 = 61 notes—[double 16 ft. and open 8 ft.].
principal, 4 ft. (one pipe smaller than open 8 ft., $\frac{1}{4}$ mouth).
fifteenth, 2 ft. (scale $1\frac{5}{8}$ in. CC, 1 in. ten. C, $\frac{1}{4}$ mouth CC to BB, $\frac{2}{7}$ mouth, ten. C up).
twenty-second—CC to F^2=42 notes (scale $\frac{15}{16}$ in. CC, $\frac{2}{7}$ mouth).
second principal—$F\sharp^2$ to C^4=19 notes (scale as at 1 ft. C=$1\frac{1}{8}$ in., $\frac{2}{7}$ mouth, slotted).
twelfth—mid C to C^4=37 notes
nineteenth—mid C to C^3=25 notes
fifth—$C\sharp^3$ to C^4=12 notes
} scale as at 1 ft. C =$1\frac{1}{16}$ in., $\frac{1}{5}$ mouth.

Assuming the 16 ft., 8 ft., 4 ft. and 2 ft. to have separate draw-stops, the remaining ranks controlled *en bloc* by one draw-stop can be set out thus :

CC to mid B=24 notes—22nd only.
mid C to F^2=18 notes—12th, 19th, 22nd.
$F\sharp^2$ to C^3= 7 notes—8ve, 12th, 19th.
$C\sharp^3$ to C^4=12 notes—5th, 12th, 8ve.

61 notes.

The complete scheme may be planned as follows, the 16 ft. rank being represented by $\frac{1}{2}$, the 8 ft. by 1, and the 4 ft. by 8 :

CC to mid B=24 notes—$\frac{1}{2}$, 1, 8, 15, 22.
mid C to F^2=18 notes—$\frac{1}{2}$, 1, 8, 12, 15, 19, 22.
$F\sharp^2$ to C^3= 7 notes—$\frac{1}{2}$, 1, 8, 8, 12, 15, 19.
$C\sharp^3$ to C^4=12 notes—$\frac{1}{2}$, 1, 5, 8, 8, 12, 15.

61 notes.

2. FLUTES.—Under this heading are grouped all those stops in an organ whose tone is characterised by a deficiency of upper partials. Flute tone may be obtained by four principal methods of voicing :

(1) from stopped pipes ;
(2) from high-mouthed open pipes ;
(3) from open wood pipes with square blocks ;
(4) from double length open or stopped pipes overblown to their harmonic.

We propose to deal with the stopped and open pipes in turn.

A. Stopped pipes may be made of either wood or metal. There are two kinds of wooden stopped pipe, the ancient and the modern. The ancient type, nearly always called "stopped diapason," is a large scaled pipe with a square block and hollowed cap fitted a trifle below the level of the nicked edge of the block (see Fig. 33 *a*). The mouth is kept low, and the foot is well plugged to prevent overblowing. The treble notes are nearly always good, but below mid C the tone is usually too "woolly," and the practice of Victorian builders of perforating the stopper with a view to adding brightness to the tone only resulted in creating a hybrid nasality.

The modern type, introduced by Schulze and usually called *gedackt*, consists of a smaller scaled pipe with a bevelled block and a flat cap fitted flush with the block-edge, which is not nicked. The mouth is cut up fairly high and little or no plugging is used at the foot, as there is small risk of overblowing (see Fig. 33 *b*). The modern pipe is preferable because it produces a bright interesting tone of good pure quality. The stoppers are best not perforated.

The metal stopped pipe is a thick metal pipe fitted with wooden stoppers. The mouth is high and the upper lip pulled outward (convex). Schulze used cork stoppers ; but most builders now use pierced cork-lined wooden stoppers.

Various scales of stopped pipe, both of wood and metal, with all kinds of mouth are fancied by various builders. A large scale metal or wood pipe with a narrow mouth is used by different voicers and called by their own pet names, such as tibia minor, cor de nuit, tibia clausa, ocarina, etc.

The *rohr flöte, flute à cheminées, chimney flute* associated with the

work of Snetzler is a large scaled metal pipe capped at the top, with a narrow tube (chimney or reed-tube) projecting perpendicularly from the centre of the cap. It is tuned by its ears, which are made large enough for the purpose. The tone is most charming. The *quintatön* (quintam tenens) is a stopped pipe (usually of metal) of rather large scale, with a low mouth fitted with a bridge; when blown it sounds its prime and its twelfth simultaneously.

The *zauberflöte* is a stopped pipe (usually of metal) overblown to speak the twelfth *instead of* the prime. In order to make it usable in 8 ft. pitch, the pipe has to be made of triple length. It was introduced by Snetzler, and developed by William Thynne.

The *bourdon* is a 16 ft. stopped pipe and may be made in any of the ways above described. It is best confined to the pedal organ, and as it is an important stop, being the cheapest and most economical form of pedal bass, a few words on its construction may not be out of place.

The English builders of the Victorian period employed large scales and low mouths for the bourdon, a very common scale being 9 in. by 7 in. at CCC, but as much as 12 in. by 10 in. is to be found in some organs. The vertical-edged block characteristic of the English type of wooden pipe naturally demands a large scale to counterbalance the low mouthing, otherwise a distressing "cough" precedes the speech of the pipe. The adoption of the wedge-shaped block (Fig. 33 *b*) provided a welcome remedy, enabling smaller scales to be used, and thus permitting greater economy of space and material. Quite a good pedal bass can be constructed from even so small a scale as 4 in. by 3 in. for the 16 ft. pipe (CCC), by bevelling the block in this way, and cutting the mouth sufficiently high. As a rule, however, a larger scale is desirable, as for instance 6½ in. by 5 in. (Schulze at Armley) or 8 in. by 5¾ in. (Schulze at Hindley). A really ponderous tone can be obtained from a pipe of this kind, scaled 9 in. by 7 in. at CCC, with a leathered upper lip and block ("clothed flue"); indeed, where height is not available for a 16 ft. open pipe, this treatment of a half length pipe creates a very tolerable substitute. The 32 ft. *sub-bourdon* is not a success below GGGG, owing to the fact that any attempt to get the wind to reach the upper lip makes the pipe speak its twelfth. From GGGG to CCC the pipes can be made all of the same scale, *e.g.* 10 in. by 8 in., with bevelled blocks and clothed flues.

B. Open flutes comprise the following principal varieties of pipe: clarabella, hohlflute, waldflute, and the harmonic flutes.

The *clarabella*, *hohlflute* and *waldflute* represent different types of open wood pipe, the clarabella possessing the same block and cap as the old English stopped pipe, the hohlflute having a bevelled block, and the waldflute an inverted upper lip and sunk block (see Fig. 33 *c*).

There are, however, many kinds of open wood flute, with various names assigned to them according to the voicer's fancy, *e.g.* the triangular-shaped pipe with or without the inverted lip, the cylindrical pipe (introduced by Schulze at the 1851 Exhibition), the large-scaled clarabella with leathered upper lip known as the Hope-Jones *tibia plena*. The mouth may be placed on either the wide or the narrow side of a rectangular pipe; as a rule the narrow side is chosen. There is also Haskell's "saxophone," which is a waldflute fitted with ears and a bridge and well blown at the foot, and the German "doppelflöte," which possesses two mouths placed back to back. The latter, however, may be a stopped pipe.

Metal flutes are made by cutting up the mouth of a diapason until flute tone is produced. If the scale is not too large, a good quality can be obtained by this method. The lower octaves of the harmonic flutes are usually made in this way.

The *harmonic flute* possesses a double-length pipe overblown to speak its octave note, the prime being eliminated by means of one or more holes bored at the node (*i.e.* more or less in the middle of the speaking-length).

The larger scaled harmonic flute is often called "concert flute" or "orchestral flute," while the smaller scaled pipe is named "flauto traverso." Heavy pressures are preferable for these pipes, especially for the larger pipes of harmonic construction. As a rule, the mouth is cut up rather high and arched, without ears—but it is much better to provide ears and keep the mouth as low as possible, the node-holes being pierced at a distance of two-fifths up the pipe (measuring from the mouth). The pipes below 4 ft. in length (giving 2 ft. tone) can be made of the ordinary length and treated like a metal hohlflute (*q.v.*).

The 16 ft. octave of the open flute is always made of wood, and used to be labelled "Open Diapason 16 ft." on the draw-stop knob, a name which is obviously incorrect. Hope-Jones' title "tibia profunda"

can hardly be improved upon, as it exactly describes the tone, but "open flute 16 ft." would also meet the case. The block is vertical-edged, as in Fig. 33 *b*, and the scale is large, as much as 16 in. by 14 in. being used for the 16 ft. pipe. The 32 ft. octave is made similarly, but when this deep pitch is reached it is almost impossible to differentiate between flute and diapason tone, and the diapason block (sharp-edged) and cap may be used if desired (as, for instance, at Armley), or else the pipes may be constructed in metal (as at Exeter Cathedral and the Royal Albert Hall, London).

3. STRING TONE.—This is obtained from pipes which are specially scaled and voiced to give chief prominence to the upper partials at the expense of ground tone. String stops therefore present a complete contrast to flute stops, while the diapason in its equipment of overtones stands more or less midway between the two.

There are two rival methods of producing this class of tone from organ pipes; one is by using a *metal* pipe, the other is by using a *wooden* pipe.

It was Schulze who introduced the glories of "wood string tone" (as it is called) into this country, his pedal 'cello at Armley and pedal violone and great contra viola da gamba at Hindley being famous examples of string voicing, but it was William Thynne who in 1885 first showed what could be done with the metal pipe, and it is exceedingly doubtful whether the more modern examples of wood and metal string stops can really substantiate their claim to be an "advance" upon the best work of these earlier pioneers. The fundamental principles of voicing and treatment common to *all* string-toned pipes are briefly these:

(1) small scales;
(2) a generous supply of wind, with heavy pressure for preference;
(3) bridges or rollers applied to the mouths of pipes previously made to speak the octave or the twelfth.

Let us deal with the metal pipe first. The largest scale from which a real viol[1] can be produced is $3\frac{1}{16}$ in. at CC (8 ft.), $1\frac{7}{8}$ in. at tenor C (4 ft.), while the smallest practicable scale is $1\frac{1}{2}$ in. at CC, 1 in. at tenor C. Hope-Jones introduced at Worcester Cathedral in 1897 the tiny

[1] The generic term for metal string stops.

scale of $1\frac{1}{16}$ in. at CC (voiced by J. W. Whiteley), but when the middle octave is reached it is not possible to reduce the 1 in. at tenor C scaling. William Thynne's usual scale was $2\frac{1}{2}$ in. at CC, $1\frac{1}{2}$ in. at tenor C, $\frac{15}{16}$ in. at mid C, and perhaps the finest examples of his voicing of these particular stops are the viole d'orchestre and violes celestes in the swell at S. John's, Richmond. It is generally believed that the latter was the smallest scale ever used by this master-voicer, and that the modern small-scaled viol was unknown before 1895, when J. C. Hele introduced his $1\frac{1}{2}$ in. CC "salicional" into the organ in the Marylebone Presbyterian Church. As a matter of fact, the author has personally seen a viol voiced by William Thynne whose scale is 1 in. at tenor C, though it is true it has no bass octave, and the tone of these pipes is far more exquisite than can be expressed in words.

The ratio of diminution in the relative scaling of these small diameter pipes must maintain a very much slower progression than that of the diapason. The latter halves its octave diameters on the 16th or 17th pipe, whereas the viol halves on the 20th to the 22nd pipe (see Chapter IV.). The mouths are fairly narrow at CC (8 ft.), usually $\frac{1}{5}$ or $\frac{2}{9}$ circumference, and gradually increase their width during the ascent, so that the upper or treble octaves often possess a $\frac{2}{7}$ mouth. The best *average* width of mouth is $\frac{2}{9}$. As a rule, when powerful viols are required (and for church organs a viol enclosed in a thick swell box needs to be powerful) the scale should not be less than $2\frac{1}{2}$ in. at CC (8 ft.), $1\frac{1}{2}$ in. at tenor C, the smaller scales being reserved for special ethereal effects in the solo or echo departments. It is much easier to voice a viol on heavy wind, especially from middle C up, the reasons being that the mouths can then be cut up higher, and the speech can be quickened. With lighter wind-pressures it is very difficult to eliminate the "spit" which immediately precedes the attack of the note, and when too great a supply is admitted at the foot, the note "wobbles." It is also by no means easy with light pressures to secure a uniformly good tone through the series, especially from middle C up. The precise fixing of the bridge or roller (usually of wood) has to be learned from practical experience. The mouth is cut up to a height equal to a third of its width (if the latter be $\frac{2}{9}$ or $\frac{1}{4}$) or a fourth of the pipe's diameter (sometimes a little more than this according to circumstances), and in the case of a $1\frac{3}{4}$ in. or $1\frac{7}{8}$ in. (tenor C, 4 ft.) scale the pipe is made to overblow to its octave

like a harmonic flute, but in the case of the smaller scales ($1\frac{1}{2}$ in. and less at the 4 ft. pipe), it should be made to overblow to its twelfth, and *then* the roller is adjusted in such a way as to bring the note back to the prime or fundamental. Thus prime and upper harmonics are locked together and produce the required string tone. The bridge need not be entirely cylindrical, but the part that faces the mouth must be rounded, and it is easier to cut off lengths from a cylindrical wooden rod than to prepare fancy shapes. When the bridge is in position the bottom end (viewed from below the mouth) is quite close to the lower lip, leaving very little space for the air to pass between the bridge and the lower lip (and indeed none at all but for the fact that the bridge is round), while the top end of the bridge is kept at a respectable distance from the upper lip of the pipe and allows plenty of space for the pressure air to pass outside the pipe. The flue is, relatively speaking, much wider than that of a diapason pipe, and the upper lip is bevelled quite sharp and kept slightly convex. Spotted metal or tin is necessary for the best results from middle C; but either plain metal or zinc can be used for the lowest octave, and where height is limited, as is usually the case in a swell-box, the longest pipes can be mitred (*i.e.* have their tops turned at right angles) or double-mitred (having two right-angled turns) without detriment to the tone.

It is usual to slot the pipes of viols, cutting a narrow rectangular vertical piece of metal from the top of each pipe at a distance of the pipe's diameter from the top. The width of the slot is usually a quarter of the pipe's diameter, but may be a third or even a half according to the voicer's desire. Tin slides are sprung on over the slots, whose lengths are thus easily regulated for the purpose of tuning. The *timbre* of the unslotted viol is more concentrated ("tighter") and a little less pungent. The 16 ft. octave is not so successful when made of metal, as it is necessary to construct a relatively larger scale if promptitude of speech is to be secured. Up to a certain point it is possible to obtain pungency of tone, but not in a degree directly proportionate to the stringiness of the upper octaves. It is here, more especially, that the wooden pipe can hold its own, and we shall now give a brief description of its treatment for the production of string tone. The pipes are constructed as in Fig. 34, *a*, *b* and *c* showing three

of Schulze's and *d* that of Thomas Pendlebury of Leigh. The latter pipe is practically a reproduction of the metal languid and mouth in terms of wood-pipe construction, for the edge of the block is chamfered and nicked, and the whole of the flue is polished with shellac and black-leaded. The Schulze pipe is not nicked owing to the block and cap being placed flush with each other. In every case the flue is so constructed as to cause the air to be highly concentrated at the point of escape. The throat consequently recedes at an angle of at least 15° from the vertical, and usually that of 30°. The top edge of the cap is filed slightly backwards, thus directing the narrowest portion of the flue outwards and throwing the pressure air against the bridge. The position of the latter is shown in the drawings, and it will be noted that more space is allowed to intervene between the lower lip of the pipe and the underside of the bridge than in the case of metal pipes. Pendlebury's bridge has an interior parabolic curve, but most modern bridges are simply wooden rollers. The special form of bridge shown in Fig. 34 *c* is that used by Schulze for the famous violone 16 ft. at Hindley. Its chief value lies in the fact that it can be placed closer to the mouth than the other forms, the portions being cut away at each end to allow a free passage for the inner and outer air. J. W. Whiteley's "contrabasso" at the Battersea Polytechnic Institute is incidentally shown in Fig. 10.

The scales employed for wooden string-toned stops are all small, and are subject to slight variations according to the caprice of the voicer. Schulze's Armley 'cello is $3\frac{3}{8}$ in. square at CC (8 ft.), the mouth being the full width of the plank and cut up $\frac{15}{16}$ in. high. His Hindley violone is $5\frac{3}{8}$ in. square at CCC (16 ft.), with a cut-up of 1 in. bare. Rectangular pipes present less difficulty to the voicer than square ones, as the mouth can be made narrower in relation to the diameter of the pipe by being placed on the narrow side. Thus a 16 ft. pipe measuring 6 in. by $4\frac{3}{4}$ in. with the mouth on the $4\frac{3}{4}$ in. plank would be capable of giving much the same effect as the $5\frac{3}{8}$ in. square pipe, for the areas of both pipes are nearly the same, the rectangular pipe being only a quarter of an inch smaller.

The smallest practicable scale for the 16 ft. pipe is about 5 in. square; beyond this no advantage in musical tone is to be gained. Pendlebury's "violin 8 ft." is constructed in wood throughout the

compass. The scale is 2 ft. square at CC (8 ft.), $1\frac{3}{16}$ in. at tenor C (4 ft.), $\frac{3}{4}$ in. at mid C (2 ft.), and $\frac{1}{2}$ in. at treble C (1 ft.). The mouth is cut up $\frac{5}{8}$ in. at CC, $\frac{3}{8}$ in. at tenor C, $\frac{1}{4}$ in. at mid C, and $\frac{3}{16}$ in. at treble C. The tone is very fine, especially from CC to mid C, but for general use, and in combination with other stops, a well-voiced metal viol is preferable in the upper octaves. Heavy wind-pressure is a great boon to the voicer of string-toned pipes whether metal or wooden, but Schulze and Pendlebury and others have been able to bequeath to us many fine examples of wood string tone on no heavier wind than $3\frac{3}{4}$ in.

4. These three tonal categories—diapason, flute and string—having been described, we must say a few words on the subject of their miniatures.

(*a*) *Diapason.*—The dulciana is an echo diapason of small scale (usually $3\frac{1}{4}$ or $3\frac{1}{8}$ in. at CC (8 ft.) and 2 in. at tenor C), with a $\frac{1}{5}$ or $\frac{1}{6}$ mouth cut up $\frac{1}{5}$ diameter.

The salicional is a name given to all kinds of soft open metal stops, and for this reason is probably best discarded from the vocabulary of stop-names. As a rule it is a somewhat stringy dulciana, the stringiness being caused by a reduction in the scaling and by slotting the pipes. Sometimes the salicional is merely a choir organ diapason.

(*b*) *Flute.*—The flauto amabile, flûte d'amour, or suabe flute are all miniature open wood flutes with or without the inverted lip.

The corno flute, dolce, corno dolce, flauto dolce are open metal stops of small scale and high mouths. The corno flute has an inverted languid (see Fig. 32 *c*), while the dolce has an inverted conical speaking-tube. The scale of the corno flute is $1\frac{1}{2}$ in. at middle C (2 ft.), and that of the dolce $1\frac{1}{4}$ in. at the mouth and $1\frac{7}{8}$ in. at the top for the same pipe (2 ft.). The tone is in both cases soft and horny, and the power is the same as that of the dulciana. Schulze's lieblich gedackt is a small-scaled stopped metal pipe, $1\frac{1}{8}$ in. or $1\frac{3}{16}$ in. diameter at mid C (2 ft.). The upper lip is often arched and unflatted (like the corno flute). Modern voicers pierce the stoppers to facilitate tuning and to brighten the tone; but the real bell-like quality can only be obtained from a plain stopper in conjunction with a small scale.

The flauto traverso is a small-scaled harmonic flute of wood or metal, and usually employed in 4 ft. pitch.

(*c*) *String*.—The echo viol, echo gamba (*sic*)[1] and viole sourdine (muted viol) are forms of miniature-toned viols. Small scaling and narrow mouths (usually $\frac{1}{5}$) and bridges are the secret of success in this class of tone. These stops are usually slotted. The muted viol as made by J. W. Whiteley (for Hope-Jones) was a conical pipe of very small scale with a sixth mouth cut up $\frac{1}{5}$ diameter. Thynne's viole sourdine was a slotted cylindrical pipe of small scale (2 in. at CC 8 ft.) with $\frac{1}{5}$ mouth and bridge, lightly blown to preclude undue harmonic development.

The 16 ft. octave of these echo stops may be constructed in either metal or wood. All the echo flutes can be provided with stopped basses. The 16 ft. dulciana may be of metal or zinc, scaled 6 in. at the 16 ft. pipe, or it may be of wood, scaled $6\frac{1}{4}$ in. by 5 in. or even less. The echo viol 16 ft. is best made of wood, the scale for the 16 ft. pipe being $5\frac{1}{2}$ in. by $4\frac{7}{8}$ in.

Another echo effect which is very popular (and, like most popular things, condemned by the pedantic purist) is the celeste. This consists of two echo stops, such as two viols or two dulcianas, one of which is tuned slightly sharp or flat to the other, so that, when used in combination, they create an undulating effect. The two ranks of pipes should be similar in tone if the best effect is to be obtained. Sometimes three ranks are employed, one being in tune with the central pitch, the other two being flat and sharp respectively. But no particular advantage is derived from using the third rank. The celeste effect is of the greatest value in non-resonant buildings, where every other effect in the organ lacks that buoyancy and animation which constitutes the peculiar charm of a well-voiced organ situated in a resonant church. The rate of pulsation should be adapted to the aggregate *timbre* produced by the two ranks of pipes in combination. Thus, a string-toned celeste will require to be tuned to give a quicker beat than a dulciana celeste. The "wobbling" effect of a celeste tuned to too quick a beat is distressing in the extreme. Too slow a wave renders the celeste effect too obscure. So that in this as in all things it is necessary to hit the happy medium. It is usual to make the out-of-tune rank slightly softer than the in-tune one, but the best result can only be obtained from two ranks of *equal* power.

[1] How much longer are we to speak of this stop as an "echo leg"?

Another method of obtaining echo tone is to enclose stops of moderate power in a thick swell-box, which even when the shutters are fully open effectually reduces the power of the stops thus treated. A viol which might sound quite powerful on an open sound-board will be barely audible in a four-inch panelled swell-box with the shutters closed. But in this case the result does not depend for its success on the design and voicing of the pipes so much as on the effectiveness of the box.

REED-WORK

Organs may be built without reeds, but never without a flue stop. Nevertheless, scientifically voiced reeds are one of the glories of the modern organ, and no instrument of any pretensions can afford to dispense with them.

Reeds may be classified in three groups: (*a*) chorus reeds, (*b*) imitative or orchestral reeds, (*c*) echoes or miniatures of the chorus reed.

(*a*) Chorus reeds are the more important because they form part of the *ensemble* of the modern organ; indeed, they constitute the foundation-tone of the swell department (see Chapter VI., pp. 90, 91). Heavy wind is essential to the best results. There are two principal varieties of chorus reed, the "free" and brilliant trumpet type so suitable for enclosure in a swell-box, and the smooth "close" horn or "magnified oboe" type which is the product of modern reed voicers. The trumpet (or posaune) has an inverted conical tube of moderate scale (about $4\frac{1}{4}$ in. or $4\frac{1}{2}$ in. at CC 8 ft.), and its treble may be of double length and tuned to speak the octave. The tromba has a larger scaled tube (from $4\frac{1}{2}$ in. to $5\frac{1}{2}$ in. at CC 8 ft.) and should always be "harmonic" in the treble, the tone being smoother and closer than that of the trumpet.

The cornopean or horn is a rather less powerful reed than the tromba, but is similarly treated.

The tuba is the most powerful reed in the organ, and may be treated either as a giant trumpet or as a giant tromba. The scale in either case is the same as that used for the trumpet and the tromba respectively, but broader shallots with wider openings and a heavier pressure of wind are used. The "harmonic" (or double-length) portion starts

as low as tenor F if the pressure be more than 10 in. At the Royal Albert Hall, London, S. Paul's Cathedral (by Willis), and at York Minster (by Harrison & Harrison) the larger tubas are on 25 in. wind, and the tuba magna designed by Willis for the organ in Liverpool Cathedral is to be on 50 in. There is a great deal to be said in favour of enclosing all chorus reeds, especially in church organs, for then they are more generally useful for the accompaniment of vocal music. All reeds standing on open chests should be hooded to prevent dust falling down the tubes. The 16 ft. octave of the chorus reed, whether used as a manual double or as a pedal stop, is not subject to much variation in its design and treatment. Smoothness and closeness of tone should always be aimed at. The tubes may be made of either metal or wood, but the latter material is only used for the pedal stop. Zinc is permissible, provided the tips of the tubes are made of the standard metal. These long tubes are best mitred[1] as shown in Fig. 37, then if the mitred portion is made of metal, the upward continuation can be made of zinc.

The 32 ft. octave is continued down on the same lines; but as the pipes get larger, the tongues become too heavy to move promptly without a "pneumatic starter," a motor being attached to the tongue which on being inflated sets the tongue in motion; or else a couple of motors may be applied—one to start, the other to check the tongue. A single motor which holds the tongue against the face of the shallot until released by depression of the key was employed by Willis at Lincoln Cathedral, while the double motor was used by Walker at York Minster.

One of the most effective 32 ft. reeds in this country is that recently added by the present firm of Willis to their fine organ in Huddersfield Town Hall; it stands on 12 in. wind, and its treatment approximates very closely to that of the diaphone, the tubes, shallots, blocks and boots being of wood, while the weighted brass tongue with its tuning spring is retained.

(*b*) Reeds voiced in imitation of their orchestral prototypes are not essential to the tonal scheme of the organ, but few organists would vote in favour of their exclusion. Such are the orchestral oboe,

[1] Usually lack of height necessitates this, and as dust is thereby effectually precluded, what is often a necessity is always a virtue.

clarinet, corno di bassetto, cor anglais and vox humana. They should always be enclosed in a swell-box. The *timbre* of each depends mainly on the shape and length of the tube employed, and a glance at Fig. 39 will suffice to indicate their distinctive form. The shallots and tongues of the orchestral oboe are very narrow, but those of the clarinet and vox humana are of normal size; in fact, that for the clarinet may be on the broad side. The orchestral oboe is often given the "oboe tube" (see Fig. 39), but made smaller in scale, and this with the narrow shallot and tongue induces that thin piercing tone which characterises the orchestral instrument. Some voicers cap and slot the tubes of all imitative reeds, but this is not necessary for the clarinet and vox humana. The 16 ft. octaves are constructed in the same way as the smaller pipes. Very often, however, a bassoon bass with half-length tubes (usually capped and slotted) acts in lieu of the real downward continuation, but this is by no means an example to be copied.

(*c*) The echo trumpet and the echo tromba or horn is generally called the "oboe," a curious name which is differentiated from the orchestral stop by lacking the orchestral prefix. The shape of the oboe tube is that shown in Fig. 39.

The tone may be that of an echo trumpet or of an echo horn, according to the method of voicing employed. The bells may be capped and slotted, or else partially capped as shown in Fig. 39. This stop is nearly always found in the swell organ. The 16 ft. octave (contra oboe) possesses a very beautiful smooth soft tone, and whether enclosed or not is of incalculable value to the tonal architect. The tongues of chorus reeds are curved to give a shorter vibrating length than those of the imitative and echo trumpet reeds. In the case of the latter the curve is slighter and more longitudinally distributed. This class of tongue curvature is known as the "light pressure curve," and ensures a satisfactory tone from pressures below 5 in.

In this survey of the principal varieties of flue and reed stops used in the modern organ the author has expressly omitted rare and fancy names, which only tend to confuse the reader's mind and possess no value whatever. The student must also bear in mind that all organ stops are capable of being used in 16 ft., 8 ft., 4 ft. and 2 ft. pitch, but that as a rule and unless otherwise stated the construction of these

registers follows a uniform and regular design. It is not, therefore, invariably necessary to speak of the complete tone-family when describing the characteristics of a certain stop. Those, for instance, who have grasped the method of construction and treatment of the 8 ft. trumpet, consisting as it does of 61 pipes (5 octaves), will have no difficulty in making and voicing a double trumpet 16 ft. or a clarion 4 ft., and the same applies to the majority of other stops, both flue and reed. It is very important that the organ stop should be viewed not as an 8 ft. or unison register, but in its *complete* state, as a rank of pipes ranging from the longest to the smallest practicable pipe. Each definite tone-colour is then represented to the mind as a master-stop or primary rank of pipes which it is the object of the designer to introduce into his scheme in as complete a form as possible. The question of tonal design will be dealt with in the concluding chapter.

CHAPTER IV

THE ART OF VOICING

In the previous chapter we endeavoured to describe the various sound-producing parts of the organ—in other words, the different kinds of pipes employed by organ-builders in the production of organ tone. We have now to consider the scientific principles affecting (I.) the speech of the individual pipe, and (II.) the regulation of a series of pipes comprising one complete stop or rank. Those who are not acquainted with the technical terminology of organ pipe construction and voicing are advised to read this chapter carefully through as an introduction to the study of Chapter III. They must also master the various parts of the flue and reed pipe which are shown in Figs. 32-40, and for this purpose there is nothing like having actual specimens of organ pipes at one's disposal.

I. The precise quality or *timbre* of a musical note is determined both by the *nature* and by the *degree* of development which is given to the series of upper harmonics or partials. We know that the harmonics or partial tones of a musical note consist of the prime or ground tone, the octave, the twelfth, the fifteenth, the seventeenth, the nineteenth, the flat twenty-first and the twenty-second, and it is possible to voice a low-pitched organ flue pipe in such a way that anyone blowing through it with a graduated increase of pressure may cause it to speak each one of these harmonics from the prime to the twenty-second in their due order of succession. Other harmonics besides these are capable of development but they are discordant, and these "secondary harmonics" are only discernible in badly voiced pipes.

When a musical note produced from a flue pipe is characterised by an ample harmonic development, so that *all* the upper partials (*i.e.* the overtones sounding above the prime) are prominently represented up to the twenty-second and tend to obscure the prime, it belongs to the category of string tone; when the note is deficient

in overtones, and the prime is encouraged in consequence, it belongs to the category of flute tone; while if the golden mean be struck between these two extremes, diapason tone is obtained. Thus we see how the *timbre* of a note is dependent on the *degree* of harmonic development present. If, however, *certain* partials are suppressed in order to lend prominence to the others, or if all the partials are suppressed in favour of *one*, we obtain certain peculiarities of *timbre*. A good instance of this is afforded by the clarinet (the orchestral instrument) whose *timbre* is characterised by the prominence of the *odd* series of harmonics (the prime, twelfth, seventeenth and flat twenty-first), the even series (octave, fifteenth, nineteenth and twenty-second) being reduced to a negligible quantity. By constructing an organ pipe on a similar principle we may obtain a more or less passable imitation of the orchestral instrument. This can be effected by employing a straight narrow tube for a reed pipe (see Fig. 39) and by plugging the top of a flue pipe with a stopper, which process sends the note of the pipe down to the octave below and suppresses the even series of partials. Or again, certain upper partials, such as the seventeenth and the flat twenty-first, may be *reinforced* by the technical process of "slotting" an open flue-pipe (*i.e.* cutting out of the top of the pipe a narrow rectangular slot or slit in a vertical line, starting at the distance of the pipe's diameter from the extreme top end, as shown in Fig. 38), or by boring a small hole through the stopper of a stopped pipe, with the result that a variable degree of *nasality* is imparted to the tone. Or again, a pipe can be so constructed as to speak one of its upper partial tones, the prime being altogether eliminated. This is effected by overblowing an open flue pipe to its octave, the prime being eliminated by the process of boring a hole at any point near the centre of the speaking length of the pipe; or by overblowing a stopped pipe to its twelfth or its seventeenth, the prime being eliminated by keeping the mouth low and boring a node-hole.[1] Or again, the stopped pipe may be made to speak the prime simultaneously with the twelfth or seventeenth by the application of a bridge in front of the mouth. In these various ways the *nature* of the harmonic development determines the particular *timbre* of the note.

[1] The application of the harmonic principle to reed pipes is dealt with in its proper section on p. 79.

In the production of organ tone, therefore, the voicer has the control of a number of factors which contribute either to the *harmonic* or to the *non-harmonic* tendency in the speech and tone of organ pipes. It is his object to encourage or to discourage, as the case may require, the prominence of one or more upper partials, and also to determine the power (or degree of vibrational intensity) of the note ; at the same time he must produce a note of musical beauty.

The following are two lists of factors which influence the speech and tone of flue and reed pipes respectively :

FLUE PIPES

1. The scale (*i.e.* diameter) of the pipe-body.
2. The area of the mouth (*i.e.* its width and height).
3. The shape of the languid of a metal pipe, and the shape of the block of a wooden pipe.
4. The adjustment of the relative positions of the upper and lower lips and of the languid of metal pipes.
5. The shape and position of the cap of a wooden pipe.
6. The character of the nicking.
7. The pressure and the volume of the wind supplied from the sound-board.
8. The size of the bore of the pipe-foot.
9. The employment of various devices and accessories.
10. The material of which the pipe is made.

REED PIPES

1. The shape and length of the tube (or resonating body).
2. The scale (or diameter) of the tube at the top.
3. The pressure of wind from the sound-board.
4. The shape and size of the shallot (or reed).
5. The shape and size of the shallot opening (or orifice).
6. The thickness, width, vibrating length and curvature of the tongue (or brass vibrator).
7. The employment of various devices and accessories.
8. The material of which the tube is made.

Let us deal with metal flue pipes first.

Generally speaking the *power* of a note is regulated by the size of the scale and of the foot-bore. A large scale and a large bore normally produce a loud note, while a small scale and a small bore normally produce a soft note. Other factors bear a more or less important part in the regulation of power, such as the area of the mouth and the wind-pressure employed, but it is the scaling and the wind supply at the foot that exercise the greatest influence.

When we come to the subject of the quality or *timbre* of a note, we are embarking upon an almost boundless ocean of possibilities. It is only possible in a book of this scope to indicate the fundamental principles which govern the art of organ pipe voicing.

The upper partials of a metal flue pipe-note are normally encouraged by the following factors :

1. Small scales.
2. Low cut up of mouth.
3. (*a*) Concave and (*b*) bevelled upper lip.
4. (*a*) Raised and (*b*) acute-bevelled languid.
5. Fine nicking.

The upper partials are normally discouraged by :

1. Large scales.
2. High cut up of mouth.
3. (*a*) Convex and (*b*) thick, arched or leathered upper lip
4. (*a*) Depressed, (*b*) obtuse-bevelled, (*c*) inverted languid.
5. Bold nicking.

The promptness of the pipe's speech, known as the "attack," is affected by the relative positions of the upper lip and the languid. When the upper lip is pressed inward (*i.e.* concave), and also when the languid is raised upward, the speech tends to "come on" slowly, until by pressing in the lip too far, or raising the languid too high, the pipe is silenced altogether. On the other hand, when the upper lip is pulled outward (convex), and also when the languid is pressed downward, the speech is quickened, until by pulling the lip out too far, or depressing the languid unduly, the pipe flies off to its octave. In

short, the speech is slow when the stream of wind is directed too much *outside* the mouth of the pipe, and is quick or " octavy " when the wind is directed *into* the mouth. There is a golden mean between these two which the voicer must strike if the speech or " attack " is to be perfect. Then again, the correct relative positions of the upper lip and languid vary with the volume of wind supplied to the pipe, so that it is necessary to decide at the outset the precise power required before " setting " the mouth.

It used to be thought that the most important part of the technique of voicing was the nicking of the pipe, but this is only one of many processes which combine to " put the pipe on its speech." Small notches are cut into the languid and lower lip so that they resemble the teeth of a saw, and they are put there to prevent the pipe from " buzzing " its note by converting the flue (*i.e.* the narrow passage between the languid-edge and the lower lip through which the wind passes up into the pipe) into an atomiser ; the wind, instead of streaming up against the edge of the upper lip in the form of an air-belt, is distributed into a number of air-columns and is thus better focussed on to the upper lip. For the production of delicate or stringy tone, the nicks should be numerous (*i.e.* fine), while sparse and bold nicking is more suited to the production of bold or fluty tone. Ears are also soldered on at each side of the mouth of the larger pipes for the purpose of controlling the stream of wind.

The area of the mouth is another important factor. We know that if the mouth is cut up high the upper partials are less prominent than if the mouth is kept low (in fact, cutting up the mouth often results in cutting out the upper partials). Now *widening* the mouth normally exaggerates its existing harmonic condition : a low mouth made wider produces more string ; a high mouth made wider produces more foundation, the scale and wind supply in both cases remaining constant. The narrowing of the mouth has the opposite effect, making a low mouth produce less string and a high mouth less foundation, under equal conditions of scaling and wind supply. Consequently the precise width of the mouth must first be decided upon by the voicer and the height or " cut up " of the mouth be arranged to suit.

This is the place to explain the technical terms used by organ-

builders in reference to the measurement of pipe mouths. The area of the mouth consists of the width multiplied by the height.

The *width* of the mouth is measured in accordance with the proportion it bears to the internal circumference of the pipe-body. The circumference of a pipe is ascertained by multiplying its diameter by 22 and dividing it by 7. Suppose, therefore, that a pipe is $3\frac{1}{2}$ in. in diameter, and its mouth is $2\frac{3}{4}$ in. wide; the mouth in this instance is a quarter of the circumference.

The *height* of the mouth is measured in two ways. It may be measured in accordance with the proportion it bears to (*a*) the internal diameter of the pipe-body, or else to (*b*) the width of the mouth. There are advantages and disadvantages connected with either method. The diameter of the pipe is taken from the top of the speaking-length, and this part of the pipe is not always "true." On the other hand, the width of the mouth is a variable factor, and a varying standard is apt to be confusing to the student. The former is the mathematical method, the latter the pipe-maker's method of measurement. If the mouth of the above-mentioned pipe ($3\frac{1}{2}$ in. in diameter) is $\frac{7}{8}$ in. in height, it is said to be "cut up a quarter of the diameter," or, adopting the pipe-maker's phraseology, "cut up a third" of its width. The area of the mouth may thus be expressed by the formula "a quarter by a quarter," signifying that the mouth is a quarter of the pipe's circumference in width and a quarter of the pipe's diameter in height; or by the formula "a quarter by a third," if the pipe-maker's method be followed. The practical limits of the width of a pipe-mouth range from $\frac{2}{7}$ to $\frac{1}{6}$ circumference.

The shape and style of languid employed also materially affects the tone. The early builders made their languids thinner than we do to-day, and the edge was cut into a more obtuse bevel (at an angle of 15° from the vertical). The modern languid is thicker and has an acuter bevel (at an angle varying from 30° to 45°). It is not possible to obtain string tone with the earlier type of languid, nor does it suit the smaller scaled pipes; hence the dulcianas of Snetzler (who introduced them into this country) are by no means model examples of this stop. But for a certain type of diapason and flute these languids are invaluable. The inverted languid (which is not nicked) is also only suitable for certain stops, such as the larger pipes of

diapasons and for flutes. These three types of languid are shown in Fig. 32 *a*, *b*, *c*.

The width of the fine (or windway) is controlled by the position of the lower lip. This latter used to be straight-faulted like the upper lip, and Schulze's faulting was nearly the same except for a very slight inward curve toward the mouth at the upper edge of the lower lip. The modern pipe-maker "dubs" the lip toward the mouth, producing the curvature shown in Fig. 32 *a*. This has the effect of speeding the flow of wind in its passage from the fine to the upper lip, and its chief advantage is seen in the voicing of small-scaled pipes.

The general principle which governs the width of the fine is that a wide fine makes for power and body of tone, while a narrow fine tends to produce the opposite effect.

The quality of the metal used influences the tender of diapasons and viols. Pure organ metal consists of an alloy of tin and lead. Lead is an unmusical metal, and by no means durable; but it is wonderful what a difference is caused by the admixture of a small percentage of tin. Nothing less than 15 per cent. of tin should be used for metal pipes, unless some third substance is introduced to strifen the alloy, such as antimony. With the aid of antimony it is possible to make good durable pipes containing only 8 per cent. of tin. When the proportion of tin reaches 15 per cent. spots begin to appear on the surface of the metal, which is then known as "spotted metal," but the "best spotted metal" contains an equal proportion (50 per cent.) of tin and lead. Tin pipes (containing 90 per cent. of tin) were commonly used by Continental builders, but are far too costly and too light for general adoption. Thick plain metal (containing eight per cent. of tin with and fifteen per cent. of tin without antimony) is the best for diapasons, spotted metal and tin for the small-scaled soups. For the larger diapasons, the plain metal is best unplaned (i.e. left in the condition it assumes after being removed from the casting-bench, with the impression of the cloth still retained). Zinc is only permissible for the largest pipes of diapasons, veils and stopped flutes, and only the "hard-rolled" (not the "baked") metal should be used in organ building.

Before a pipe can be ready for voicing, the question of the quality of the metal, the size of the scale, the shape of the languid and the

width of the mouth must be definitely decided, in order that the pipe-maker may construct the pipe up to this point. The voicer then takes charge of it. He decides the pressure of wind, and proceeds to cut up the mouth to the approximate height required and to nick the languid. The pipe is thus "put on its speech," and can be tried on the voicing-machine. The various parts of the pipe—the lips, languid and foot-bore—are adjusted, and various devices may be resorted to, such as bevelling the upper lip for keen tone, burnishing, leathering or arching it for dull tone, slotting the pipe at the top, affixing a bridge or a beard between the ears. The pipe has also to be cut down to the correct pitch (allowing for the sharpening effect of slotting if this is resorted to), as the pipe-maker always makes the pipe a little too long in order to allow a margin on the safe side.

The treatment of wood pipes has much in common with that of metal pipes, only as we have to deal with an unpliable material there are obviously certain points of difference in the *modus operandi.*

The scale, the shape of the block and of the cap, the height of the mouth, have all to be decided on before the pipe is made. The *width* of the mouth is determined by the width of the plank on which the mouth is placed. The mouth of a square pipe is equivalent to $\frac{2}{7}$ circumference of a metal pipe. In the case of a rectangular pipe, the depth (or wide side) of the pipe corresponds to the diameter of a metal pipe, while the width (or narrow side) of the pipe corresponds to the width of the mouth of a metal one. Thus if the metal pipe be $3\frac{1}{2}$ in. in diameter with a mouth a quarter of the circumference in width, the corresponding wood pipe will be $3\frac{1}{2}$ in. by $2\frac{3}{4}$ in., or if the $3\frac{1}{2}$ in. metal pipe have a $\frac{2}{7}$ mouth, the corresponding wood pipe will be $3\frac{1}{8}$ in. square. When the wood pipe is made, there remains but little for the voicer to do to it except to give it a few finishing touches. He determines the wind-pressure, and adjusts the wind supply at the foot-bore by plugging it with small pieces of wood if required, or else a small metal tip may be fixed on to the wooden foot, which then can be regulated in the same way as the metal pipe-foot. Nicking is only applied to the pattern of stopped and open wood pipe which is fitted with a square flat-edged block and a hollowed cap set a trifle below the top edge of the block (see Fig. 33 *a*). Both block and cap may be nicked, but it is not necessary to nick the cap. It is also applied to

the Pendlebury wood string-toned pipe whose block and cap are constructed similarly to the metal languid and lower lip; but the pipe which is fitted with the bevelled block and cap set flush with the top edge of the block shown in Fig. 33 *b*, and introduced to this country by Schulze, is not nicked. In wood string-toned pipes the bridge is fixed by the voicer except in the case of the pipe shown in Fig. 34 *a*, where the bridge has only one position allowed for it. This type of cap and bridge answers perfectly for diapason basses, and was invented by Schulze and employed by him in the 32 ft. open bass at Armley. The only adjustment available to the voicer corresponding to the raising of the languid and the pressing in of the upper lip of the metal pipe is the filing of the inside top edge of the cap in an outward direction. This is only done in the case of diapason and string-toned pipes in order to prevent the pipe from "coughing" or speaking the octave before settling on to its proper note. The upper lip is bevelled to a sharp edge for diapason or string tone and kept blunt for flute tone. The lip may also be leathered for a certain type of flute tone, or it may be arched. The same rules apply to the wood pipe in the matter of the height of the mouth as to the metal pipe; the measurement is, however, always taken from the width of the mouth.

Various kinds of wood are employed; the most popular are pine, mahogany and oak. Mahogany is the best wood for hot climates, but well-seasoned pine serves excellently in England. The cap and the face of the block is usually made of mahogany or of oak. Satin walnut, pear-tree, box, teak and sequoia are occasionally found in some organs. But the great desideratum is the employment of well-seasoned, unknotted, stout planks, which not only benefit the tone but resist the ravaging hand of time.

The voicing of reed pipes, which next claims our attention, has little or nothing in common with the study of flue voicing. It is in fact a separate art, though it requires the same faculty of aural discrimination. It is impossible to teach anyone by book to become a skilful reed voicer; nevertheless the treatment of these pipes is subject to certain definite scientific laws, and anyone who is a good practical mechanic and possesses a discriminative ear for tone can in process of time and by dint of experience attain to a higher degree

of proficiency than is generally imagined. Success in reed voicing depends on:

1. The correct construction of the pipe.
2. The correct curvature of the tongue.
3. The correct use of wind-pressures.
4. The correct tuning in relation to the pitches of the reed and the tube.

1. *The construction of the parts of the pipe.*—(*a*) The *tube* or resonating body varies in *shape* in accordance with the type of reed-tone required. For chorus reeds (*i.e.* trumpet, tromba, cornopean, tuba) the tube is inverted conical in shape, the diameter at the top for the 8 ft. pipe varying from $3\frac{7}{8}$ in. to $5\frac{1}{2}$ in.

For orchestrally imitative reeds the tube is both narrower and shorter than that of the chorus reed, and each imitative reed has its own peculiar shape (see Fig. 39).

The *tip* of the tube (that part which joins the block) should be narrow. The early Victorian builders made the tips too wide, with the result that the tone was not adequately controlled at the point of juncture between the block and the tube. Those who have studied the science of human voice-production will find in this particular point a striking confirmation of the *bouche fermée* method, in which the singer is instructed to practise scales on *m-woo-ah* in order to acquire pure tone. The human voice being a reed controlled in a similar manner to that of the organ reed, it does not require much imaginative power to discern the parallelism here suggested. The *length* of the tube is a point of supreme importance. If the tube is too long, a sort of throttled or choked note results, and the tone is said to be "too close"; if, on the other hand, the tube is too short, the tone is coarse and said to be "too free." Therefore we have to find the *via media*, and it is usual to make the tube a trifle too long and then to cut it down or slot it until the pipe speaks its natural note—"tight" without being too "close," "free" and yet not harsh.

(*b*) The *shallot* (or *reed*) is made of various patterns by different voicers. The two chief types of shallot in modern use are the open and the closed. The open shallot has the orifice cut right through from the head (or base) to the tip (see Fig. 35 *b*), while the closed

shallot has a triangular or V-shaped orifice (see Fig. 35 *c*). The open shallot was invariably used by Cavaillé-Coll and other French builders; it is also used by Willis for the production of powerful free-toned chorus reeds (usually enclosed in a swell-box) of a special character. But, as a general rule, the closed shallot should be employed as ensuring a greater refinement of tone. The wider the opening at the base the broader and more powerful the note; consequently, the largest scale of shallot with the widest opening is used for the tuba in all its octaves, while a smaller shallot with a narrower opening is used for a trumpet of moderate power, and the smallest shallot and the narrowest opening is used for the orchestral oboe with a view to obtaining as thin a tone as possible.

Vincent Willis introduced the idea of "filling in" the head of the shallot with a thin plate of brass with the object of retarding the ingress of wind to the shallot, the orifice by this device beginning further up the shallot at a distance equal to about a fifth of the tuning length of the tongue. This has the effect of reducing the periodic vibration of the tongue and makes for increased power without loss of foundation-tone.

(*c*) The *tongue* is cut out of a sheet of hard brass to match the shape and size of the shallot. The thickness of the tongue is determined by the wind-pressure employed. The voicer must ascertain by experiment the *minimum* thickness that will work satisfactorily on a given pressure and on a shallot of given size, increasing the thickness from that point in proportion as the pressure and shallot opening increases. That great pioneer of the modern scientific school of reed-voicing, George Willis, introduced the system of weighting the end of the tongue of a large reed, which is now universally applied to all bass octaves and to the heavier pressure chorus reeds as far up as the one-foot C. Its object is to control the elasticity of the tongue by slowing down its vibrations, and thus to enable the voicer to reduce its tuning length and obtain a better note. Willis introduced and still uses circular brass weights, the top side being flat, and the bottom, which is screwed on to the tongue, being cone-pointed. This point has to touch the tongue as near to the base of the shallot as possible, but not on any part of the tongue which strikes the shallot. If the head (or base) of the shallot is "filled," the weight is placed further up the tongue so as to

coincide with the orifice below. Felt and leather weights of all shapes with a small piece of lead fixed on to the top side for the larger tongues and for heavier pressures are very popular with some voicers. The laminated weight (consisting of two or more layers of felt or leather of diminishing sizes) enjoyed a short vogue but is now obsolete. The popularity of the felt and lead weight is due to the fact that it is more readily made and placed, but the Willis brass weight commends itself as an integral part of a scientific system which has been evolved and brought to perfection by the Willis family. The size of the weight depends on the size and thickness of the tongue, and also on the length and diameter of the tube which is acting as a resonator. The larger and thicker the tongue and the larger the scale of the tube, the larger the weight required.

2. The *curvature* of the tongue is that department of reed-voicing which is generally considered as the most difficult. The quality of the curve must be such as to enable the tongue to roll down the face of the shallot during the process of striking.[1] This can be tested by holding the shallot (with the tongue in position) in front of a light, so that the light shines between the tongue and the shallot: then while slowly depressing the tongue with one's forefinger the darkness caused by the exclusion of light is seen to travel in even gradation along the intervening space until with the contact of the head or base of the tongue with the end of the shallot all light is completely excluded. The *quantity* of the curve varies with the thickness of the tongue and the pressure of wind employed. If the tongue is not sufficiently curved, or if it is too thin and pliable, the force of the wind will drive it too hard against the shallot; therefore the thicker the tongue and the lower the pressure the less the curvature required. The tongue may be curved by hand or on the curving machine. The latter is invaluable for the larger tongues, but most voicers prefer to curve the smaller tongues with the burnisher. The tongue is placed flat on a block of polished ebony (or of polished steel), and the tip or narrow end is clamped securely down, leaving the broad end free. The burnisher (or any thin cylindrical piece of steel) is drawn along the surface of the tongue with graduated increase of pressure, which reaches its climax at the head, and this process is repeated if necessary until the curvature

[1] This curve is parabolic in form, and is illustrated in Fig. 40.

is sufficiently pronounced. The curving machine performs precisely the same operation mechanically, the *extent* of the curve being regulated by a cam and the degree of the curvature by the tension of a spiral spring.

The curvature of the tongue has a very marked influence upon the speech and tone of a reed pipe. Assuming that the curve is correct in respect of its quality, it may yet be either too pronounced or insufficient. Too great a curve makes the speech slow, though as a rule when the note does come it is more refined in tone. When the curve is inadequate, the speech is too quick and is weak and "loose." The precise amount of curvature has to be determined by the voicer when engaged in the work of "finishing" at the voicing-machine.

3. Heavy wind-pressures are a tremendous help to the reed-voicer. The best chorus reed tone is obtained from relatively thin tongues, well curved, and, if large, weighted at the end—in fact, from any treatment that reduces the vibrations of the tongue and flattens its pitch, thus compelling its vibrating length to be shortened[1] in order to bring the pitch up again. The actual curvature, therefore, is confined to the vibrating portion of the tongue, which is defined by the position of the tuning spring. The shorter the vibrating length, the less the power, unless the curve can be increased by way of compensation. If the latter be done, slowness of speech results, and an increase in the pressure of wind alone will overcome the inertia of the tongue. These considerations lead us to this conclusion in regard to chorus reed voicing, that the best tone is to be produced from the shortest possible vibrating length of the tongue capable of giving the correct pitch, and that this length is determined by the following interdependent factors — (*a*) the minimum thickness of the tongue, (*b*) the maximum degree of weighting, (*c*) the length and scale of the tube, and (*d*) the wind-pressure available.

4. The length of the resonating tube must bear some relation to the natural pitch of the vibrating tongue if the tone of the reed is to be satisfactory. Sharpening the pitch of a reed makes the tone softer and "closer," and the speech slower, while flattening the pitch makes the tone louder and "freer," and the speech quicker. If the tube is

[1] That is, by knocking down the tuning spring.

too long, the tongue has to be shortened to pitch and the tone is too "close"; if the tube is too short, the tongue has to be lengthened to pitch, and the tone is too "free." Therefore the tube must be cut to the correct length in proportion to the pitch of the reed itself.

There are two devices familiar to voicers which are employed with the object of obtaining a smooth tone. The first is that of capping the tubes at the top and slotting them below the cap. For the smaller toned reeds this device has something to recommend it, but it is never necessary to adopt it except for a special effect or for the purpose of lengthening tubes which are found to be too short. The second is the employment of a double-length tube with a view to tuning the note to its octave. This is now universally adopted for the purpose of securing purity of tone in the middle and treble register of the louder chorus reeds, especially the tromba and the tuba. The double-length tube is not generally used below the 1 ft. C on any wind-pressure below seven inches. The heavy pressure tuba (on 15 to 25 ins.) is usually made "harmonic" from tenor F (above 4 ft. C), and the tongues are weighted up to the 1 ft. C. The diameter of the double-length tube is the same as that of the octave below (normal length), or it may be a trifle larger. The shallot and tongue are of the same size as that required for a normal tube, but the curvature of the tongue should be more longitudinally distributed.

II. Thus far we have confined ourselves to the treatment and voicing of a single representative pipe, but each stop comprises a rank of pipes which have to be regulated in such a manner as to ensure perfect balance of power and equality of tone throughout the entire range of the stop. This is also the work of the voicer, and depends partly on the relative scaling of the pipes of a given stop, partly on the finishing touches of the artist who is responsible for the tonal design of the instrument. The subject of relative scaling is purely a scientific one, for it deals with the proportion which the diameters of the pipes are to bear to each other in the successive octaves, and this is determined by the ratio of diminution in the scaling. It might be supposed, for instance, that the diameter of the 4 ft. C pipe would be exactly double that of the 2 ft. C pipe an octave higher; but this is not so: it if were, the pipes would diminish in area too rapidly and the treble register of the stop would

suffer from loss of power and body. If, on the other hand, the octave pipe were too large in scale, that is, if the ratio of diminution were too slow, the treble register would lack definition and character. The usual flue ratios are $1 : \sqrt{8}$, in which the diameter is halved on the sixteenth note above (*i.e.* the diameter at C is halved at the octave E flat above); $1 : 2\frac{2}{3}$, in which the diameter is halved on the seventeenth note (*i.e.* the diameter at C is halved at the octave E above), and $1 : 2\frac{1}{2}$, in which the diameter is halved on the eighteenth pipe (*i.e.* the diameter at C is halved at the octave F above). For viols the half-measure falls on the twentieth to the twenty-second note, and for reeds, on the thirtieth to the thirty-second note. Schulze adopted the $1 : \sqrt{8}$ ratio recommended by Töpfer, but modern voicers prefer nothing less than $1 : 2\frac{2}{3}$ (halving on the 17th) for diapasons and flutes, while Willis' standard ratio for diapasons is to quarter the diameter on the 33rd note (or "halve it on the $16\frac{1}{2}$th"). The diameter of any given pipe in the given scale can be ascertained by working out the formula $\log. d = \log. D - \frac{n}{m} \log. 2$, where d is the diameter of the upper note required, D is the diameter of the larger pipe, n is the serial number of d, and m is the number on which the half-measure is to fall. Thus if we desire to know the diameter of middle C in the ratio $1 : 2\frac{1}{2}$, given tenor C=3 in. diameter, the equation $\log. d = \log. 3 - \frac{12}{18} \log. 2$ will give us the answer, namely, $1\frac{7}{8}$ in. A rough-and-ready method can be employed by multiplying the larger diameter by $\frac{3}{5}$ to obtain the diameter of the octave above in the $1 : \sqrt{8}$ ratio, by $\frac{25}{41}$ in the $1 : 2\frac{2}{3}$ ratio, and by $\frac{5}{8}$ in the $1 : 2\frac{1}{2}$ ratio. But the pipe-maker prepares a diagram, measuring off the scale of the largest pipe (the "absolute scale") and marking the half-measure at the 16th, 17th, 18th or any other note required, and then filling in the intermediate diameters with equi-distant ordinates.

The regulation of the power and quality of the tone of a rank of pipes after every step has been taken to secure mathematical correctness of proportion consists in giving the finishing touches to this and that pipe whose power or tone does not conform to the average standard of the series. The different parts of the pipe mentioned earlier in this chapter are adjusted as required, and when all is done, it should not be possible to detect any inequalities. It is also the duty of the

"finisher" to impart to each stop in the scheme of the organ the power and quality that are necessary to ensure a perfect *ensemble* when some or all are used in combination; and this is a work which only the most accomplished and gifted artist can ever hope to carry out successfully, and determines the place which the organ is to occupy among the art-productions of the world.

CHAPTER V

TUNING

When a note is sounded with its octave above and no wave-beats are audible, it is in tune with its octave, and if the octave is absolutely true to pitch, then the lower note must also be true to pitch ; in other words, both are in tune. If, therefore, the 4 ft. diapason of the organ (generally called the principal) is in tune in the same sense as for instance a pianoforte is "in tune," every other stop of the organ can be tuned to it. If, for example, we wish to tune the trumpet 8 ft., we can draw the principal 4 ft. with it, and tune each note by eliminating the beats caused by the trumpet being out of tune with the principal. Every other stop can be subjected to the same treatment until all are in tune with the principal and with each other. Each manual is tuned independently to its own standard 4 ft. stop (usually some form of principal), care being taken to see that all the principals are in tune with each other.

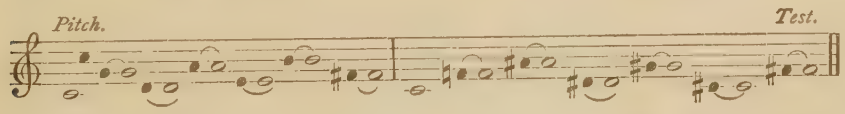
But first of all it is necessary to tune the principal itself, and this is done by "laying the bearings" of the middle octave (middle C to treble C), by which process the pitch-relationship between each semitone from middle C to treble C is definitely established. There are thirteen notes in the octave, but it is not possible to find room for thirteen perfectly tuned notes, only for twelve ; and a choice has to be made between two alternatives—either to have a limited number of perfect intervals, which means being restricted to the use of a few keys, or else to have all the notes at one's disposal by slightly tempering the intervals. The latter, known as the "equal temperament" scale, was introduced by J. S. Bach and is now universally adopted.

In "laying the bearings" the tuner has to diminish all the fifths and to widen all the fourths, at the same time keeping the octaves pure. The fifths are first tuned perfect (non-beating) and

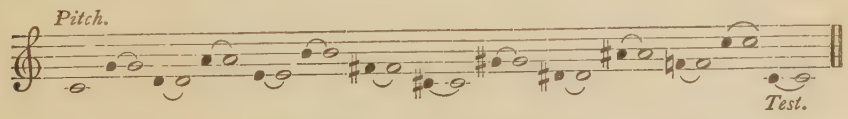
then slightly narrowed (slow-beating). The fourths are first tuned perfect, and then slightly widened. The widening of the fourth is slightly greater in degree than the narrowing of the adjacent fifth.

Take middle C for instance, and hold with it the G above. This is the fifth. Tune the G to sound a perfect non-beating interval with C below. Then slightly flatten the G, till a slow wave-beat is perceptible.

Next hold middle C and F above. This is the fourth. Tune the interval perfect and non-beating. Then sharpen the F, so that it beats with the C below. Let the beat of the C F interval (the fourth) be a little quicker than the beat of the C G interval (the fifth). The pitch of F and G will be correct in equal temperament. The reason why the out-of-tuneness of the fourth should be greater than that of the adjacent fifth (*i.e.* why F should be sharper to C than G is flat to it), is because the rate of the beats of C and F above is equal to the rate of the beats of F and C above. But the higher in the scale the interval occurs the quicker the beats; for example, the fifth treble C and G above beats much more quickly than the fifth middle C and G above. Consequently, if the fourth middle C and F gives the same beat as the fifth F and treble C which is higher up in the scale, it must beat more quickly than the fifth middle C and G, which is a lower interval. The following is the almost universally adopted scheme for laying the bearings. The intervals are tuned in the order set below, the notes to be tuned being the tailless crotchets.

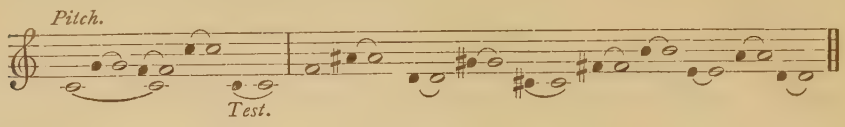
1. 

For skilled tuners the following scheme is even better, because there being no break it is capable of being more quickly carried out.

2. 

For the novice, the following is recommended, as the chief diffi-

culty in learning to lay the bearings lies in determining the vibration-number of each fourth and fifth.

3. 

This method may be explained thus:

Hold middle C on the principal 4 ft., which is the pitch-note of the organ. Now hold the G above with it and tune it *very* slightly flat until a slow beat is discernible (about 60 metronomic rate). Next hold the F with the pitch C and tune it sharp so that it beats a *little* quicker than the fifth just tempered. Then tune the octave C slightly flat to the F, making this fifth beat at exactly the same rate as the fourth F and C below. This done, the two C's (middle and treble C) should be in perfect tune.

Now hold the F and with it A♯ above, and tune the latter sharp to F so that it beats a little more quickly than the fifth F and treble C (about 160 metronomic rate). Next tune D♯ below slightly sharp to the A♯, making it beat less quickly than the fourth F A♯. Tune G♯ above sharp to D♯ and C♯ below sharp to G♯, following the same rules with regard to the rate of pulsation. Then tune F♯ sharp to C♯, and B above sharp to F♯, and E below sharp to B, and A above sharp to E, and lastly D below sharp to A, making in each case the fourth beat quicker than the fifth, and *also* seeing that every fourth beats *very* slightly slower than the next fourth above, and that every fifth beats very slightly slower than the next fifth above. Then test the fourth D G, in which the D should be slightly flat to the G; placing the hand over the top of the D pipe should make the beats quicker, while the same operation to the G pipe should bring the interval temporarily into perfect tune.

In scheme 1 the tailless crotchets of the first section are tuned flat, while in the second section they are tuned sharp.

In scheme 2 all the tailless crotchets are tuned flat.

In scheme 3 all except the first and third are tuned sharp.

Thus far the middle octave of the principal is tuned. The rest of the stop is then tuned in octaves up and down, commencing with

middle C♯ and treble C♯ in which the latter is tuned to the former, and so on to the top note, and then re-starting the downward scale at middle B and treble B, tuning the former to the latter, and so on down to the bottom C. Every note outside the middle octave of bearings can be tested by holding with it the fourth and fifth below respectively in the case of the upper register, and by holding the fourth and fifth above in the case of the lower register. It should be flat to the fifth and sharp to the fourth in the first case, and *vice versa* in the second case. The fourth must beat more quickly than the fifth, and both must be reasonably concordant. As a rule it is not necessary to apply this test to any note above the 3 in. C (*i.e.* C above treble C on the principal). If the pipes are planted tonally on the sound-board, one side should be tuned at a time, first the C side, then the C♯ side.

The principal having been tuned, all the other stops can now be tuned to it, beginning at the top note and finishing at the bottom C. Very soft stops, however, and flute stops are apt to be "drawn" into apparent tune by the principal, which is too powerful to be used as a standard. The soft stops therefore should be tuned independently like the principal by having their bearings laid as above described; while the best method of tuning flute stops is to draw the principal and another already tuned 8 ft. stop with them and to tune in the usual way.

Mixture stops should be tuned to the principal one rank at a time, the other ranks being silenced by inserting a small wad of cotton wool into the top of the pipe, unless each rank is controlled by a separate slider. All mutations are tuned perfect (*i.e.* not tempered).

The 16 ft. stops are also tuned to the principal, but the pedal 16 ft. flue stops are best tuned to the large diapason of the Great, while the pedal 16 ft. reeds are best tuned to the Great chorus 8 ft. reed. The pedal 8 ft. and 32 ft. stops should be tuned to the 16 ft., but very often these stops are extensions of master stops and are tuned in octaves to their own middle register.

The pitch of a flue pipe is altered by lengthening or shortening the speaking tube to flatten or sharpen respectively. Metal flue pipes are lengthened and shortened in two ways, either by having their tops coned in for flattening and coned out for sharpening, or by having cylindrical tinned slides clipped on to the tops of the pipes, which can

be knocked up to flatten and knocked down to sharpen. The latter is the modern method and by far the best, as it preserves the pipes from ill-usage. The larger pipes (below 4 ft.) are usually slotted at the back near the top, a strip of metal exactly fitting the slot being opened or shut to sharpen or flatten. Open wood flue pipes have tin flaps fixed on to the tops of the pipes, which can be opened up or closed down like a trap-door. The large wood pipes are usually slotted, and the slots are covered with a movable piece of wood which controls the area of the slot. All stopped pipes are obviously tuned by means of their stoppers, the stopper being knocked down to sharpen and drawn up to flatten the pitch.

Reeds are tuned by means of a small spring which shortens the tongue when tapped down and consequently sharpens the note, and lengthens the tongue when tapped up, thus flattening the note. The slots cut in the top end of the tubes, and the slides sprung on the tubes of the clarinet and vox humana pipes, are intended for regulating the power of the pipes and are not, generally speaking, to be used for tuning. There are exceptions to this rule, as for instance when a sudden alteration of temperature will interfere with the scientific relationship subsisting between the tube-length and the tongue-length; if the tongues be re-adjusted to the altered tube-length the pitch of the reed will be rectified at the expense of the tone, while the adjustment of the tube at the slot will restore the tone and pitch of the reed to its original standard.

The standard pitch of the organ has varied from time to time from C=545 vibrations down to C=517.3 vibrations. The first is the old Philharmonic pitch and is absurdly high, while the latter is the French Diapason Normal pitch, which is being generally adopted to-day as being most suitable both for the accompaniment of voices and for use in conjunction with the modern orchestra. A large number of church organs are still, however, tuned to a medium pitch, C=528 or 530, known as the Society of Arts' standard, but it is hoped that all new organs will be tuned to the French pitch.

CHAPTER VI

TONAL DESIGN

We have now to consider the problem of grouping the various tone-colours of the organ in such a manner as to bring them under the control of the performer; and we have to bear in mind that the main object of the tonal architect is to arrange the mass of stops at his disposal with a view to securing the maximum of efficiency and service from each and all without violating the canons of art or resorting to unnecessary complications.

The conventional method of tonal design consists in dividing the instrument into a number of self-contained sections, each section being provided with its group of tones (often not too obviously characteristic), while the combination of two or more sections is made possible by means of manual couplers.[1] These divisions owe their origin to historical evolution. The earliest type of organ consisted of a single row of keys operating a single stop of pipes: other stops of pipes were added, but the organist had to be content with a very limited selection of tone-colours. The next development of importance was the erection of a separate sound-board of stops of modest calibre behind the organist's back so as to enable him to hear his choir and his own accompaniment from a detached standpoint, for if the player be situated between his pipes and his choristers (the former in front and the latter behind), he must experience some difficulty in gauging the correct balance of tone in his selection of stops. Such was the probable origin of the "chayre organ" or echo great, which subsequently earned the name of "choir organ" (see p. 92), and which was responsible for the introduction of a second independent clavier to the console.[2]

[1] Octave couplers (sub and super) are often added in order to extend certain of these sections "up and down."

[2] Two *incomplete* claviers, one forming the treble, the other the bass of the great organ, were introduced in the fourteenth century, but such a contrivance cannot claim the title of a two-manual organ.

It then occurred to organ-builders to duplicate the treble portion of some of the stops and enclose them in a wooden box to make them sound softer and more remote. Here we have the introduction of a third clavier called the "echo organ." In 1712 Abraham Jordan fitted a sliding shutter to the echo box, and thus rendered the pipes in this box capable of *crescendo* and *diminuendo* effects. This led to the demand for an additional row of keys, and the first four-manual organ (worthy of the name) was erected by the Jordans in S. Magnus' Church, London Bridge, consisting of great, choir, echo and swell manuals. The "swell organ," however, usurped the place of the old echo clavier, and it fell to a later age to re-introduce the echo organ as a distinctive group of specially voiced stops standing on a sound-board in some remote recess of a large building and controlled by a fifth clavier. The fourth manual was reserved for a group of stops more or less imitative of their orchestral prototypes culminating in the formation of a "solo" or "orchestral" department, in which, inspired by the French Clavier des Bombardes, William Hill introduced the tuba family on specially heavy wind-pressure to represent the orchestral brass. Thus we can trace the development of the five-manual console, bringing under the control of a single performer the great, swell, choir, solo and echo organs or tone-groups. The pedal organ can be traced back as early as the fifteenth century as a means whereby the performer can use his feet to produce the deeper tones of his instrument.

It is not, however, the conventional *departments* of the organ (great, swell, choir, solo, echo and pedal) that we would desire to bring under critical survey, but the conventional *system of stop-classification* which is adopted by builders and organists in the drawing-up of specifications. We propose to deal with each of these departments *seriatim*, and to point out their respective peculiarities.

1. The *Great Organ* is, as its name implies, the department that contains the louder stops, so that one would suppose that "full great" (that is, the aggregate effect of all the stops of this organ) would predominate over the rest of the organs. Actually it does not do this in a four-manual instrument containing one or more tubas on the "solo organ." The great organ is, as a matter of fact, the *Diapason Organ*, containing a complete diapason structure from 16 ft. to mixtures; but the conventional "great" more often than not possesses an in-

complete diapason chorus and an incomplete reed chorus. Here is a common example of a great organ specification :

Stops.	Classification.
Bourdon, 16 ft.	*Flute.*
Open Diapason, 8 ft.	*Diapason.*
Gamba, 8 ft.	*String.*
Clarabella, 8 ft.	*Flute.*
Principal, 4 ft.	*Diapason.*
Harmonic Flute, 4 ft.	*Flute.*
Fifteenth, 2 ft.	*Diapason.*
Mixture, 3 ranks.	*Diapason.*
Trumpet, 8 ft.	*Reed.*

Here we have a heterogeneous combination of diapason, flute, string and reed tones which hopelessly violates the modern canons of tonal architecture. Instead of these incongruities, we ought to ensure the completeness of our diapason chorus by specifying a double open diapason 16 ft., two or three 8 ft. diapasons (large, medium and small), two octave diapasons, (large and small), and a series of upper harmonics —twelfth, fifteenth, nineteenth and twenty-second. Flute tone may then be introduced, and in this order—8 ft., 4 ft., 16 ft. (never 2 ft.). String tone is debarred from the great organ, being foreign to the structure. Reeds are admissible in all departments, but are by no means an essential part of the great organ scheme. They may be enclosed in a separate swell box or in the swell or solo boxes, or else they may stand on an open sound-board, but they should never stand on the same sound-board as the diapasons. The reason for this is that (1) a different (and a heavier) pressure of wind is required for chorus reeds if the best results are to be obtained from them (see Chapter III. on Reeds), and (2) one sound-board should not be permitted to carry more than eight stops, and the provision of a separate reed sound-board affords the desired relief. The upper work of the diapason chorus can be included with the reed work on this chest. On the great the reed stops should be introduced in the order 8 ft., 16 ft., 4 ft., though in some cases a double reed (16 ft.) may be the only reed in this department and impart a magnificent effect to the *ensemble*.

The list of stops comprising the complete structure may be seen at a glance as under :

Diapason Chorus.	Flute Tone. (*Supplementary.*)	Reed Chorus.
Double Open Diapason, 16 ft.	Bourdon, 16 ft.	Contra Tromba, 16 ft.
Open Diapason I., 8 ft.	Clarabel, 8 ft.	Tromba, 8 ft.
Open Diapason II., 8 ft.	Flute, 4 ft.	Clarion, 4 ft.
Open Diapason III., 8 ft.		[Mixture, 19, 22.]
Principal I., 4 ft.		
Principal II., 4 ft.		
Twelfth, $2\frac{2}{3}$ ft.		
Fifteenth, 2 ft.		
Mixture, 19, 22.		

2. The *Swell Organ* was originally an echo organ supplemented by the addition of a couple of reeds usually of 8 ft. pitch. The following is a sample :

Bourdon, 16 ft.
Open Diapason, 8 ft.
Stopt Diapason, 8 ft.
Viola da Gamba, 8 ft.
Voix Celestes (T.C.), 8 ft.
Principal, 4 ft.
Mixture, 3 ranks.
Cornopean, 8 ft.
Oboe, 8 ft.

Sometimes a Vox Humana is included, and with the help of octave couplers the *tout ensemble*, if the flutes be excluded, is capable of some success. But what does this show ? Simply that the effect of the "full swell" is obtained from its reed chorus and mixtures. The foundation of the swell organ, therefore, consists of 16 ft., 8 ft. and 4 ft. reeds and a series of ripieno harmonics, 8, 12, 15, 19, 22.

This constitutes the "secondary chorus" of the organ, the great being the primary chorus. The addition of flue-work (diapasons, strings and flutes) and of fancy reeds to the swell reed structure is, and probably always will be, a matter of individual choice, but be it

remembered, if only for the sake of clear thinking, that enclosed flue stops and imitative reeds belong to the echo and solo (or orchestral) divisions of the organ and not to the modern swell. This does not mean that all these stops should be excluded from the swell *manual*; there is no reason why any stop should not be playable on any manual, for greater interdepartmental facilities form the key-note of modern organ design; but it merely tends to confusion of thought to heap all kinds of stops on to a sound-board and after enclosing the lot in a swell box to call this conglomeration of tone-colours the "swell organ."

It is necessary also to have clear ideas as to the *type* of reed tone which alone can impart to this organ its characteristic qualities. The horn or cornopean has for so long become the traditional chorus reed of the swell that builders have allowed themselves to be blinded to the possibilities of the true type of reed for this department. The horn is a name that connotes breadth and smoothness of tone, and voicers have been labouring under the delusion that the successful treatment of the reed on these lines will ensure an equally successful swell organ effect. No greater mistake could have been made. Large-scaled reeds, especially in the tenor, middle and treble registers of their compass, are an abomination in the swell, and the very first reform which builders are called upon to introduce is that of re-labelling the swell chorus reed a *trumpet*, and abolishing for ever the misnomers horn and cornopean. Then it will be understood that what is required is not a "fat-toned horn" but an "angry-toned trumpet" capable of imparting to the *ensemble* that characteristic brilliance and "clang-tint" for which Henry Willis' swells are so justly famous. This, in brief, is the foundation of the true swell organ:

Double Trumpet or Contra Tromba, 16 ft.
Trumpet, 8 ft.
Clarion, 4 ft. (harmonic treble).
Ripieno Mixture, 8, 12, 15, 19, 22.

3. The *Choir Organ* has of late years developed into a "collective manual" containing echo and solo tones of all kinds. When the stops of this department are not enclosed in a swell box they practically represent the great organ in miniature with the usual addition of one

or more orchestrally-toned reeds such as the clarinet and the orchestral oboe, though these latter are sometimes enclosed in a swell box of their own. But many modern choir organs are totally enclosed, and the reason for this may be traced to the modern performer's demand for the provision of an independent group of expressive soft stops to serve as an accompaniment to solo stops in the swell organ, for few things exasperate a player more than, for instance, to be compelled to "accompany his swell oboe which is in a box on the choir dulciana which is outside the box." In a three-manual organ (possessing no independent solo or orchestral clavier) the third manual would naturally be made the vehicle for a group of solo stops, reed and flue; and these always demand enclosure. Hence we now find so many modern examples of the choir organ comprising a collection of echo and orchestral tones enclosed in a separate swell box.

The origin of the term "choir" as applied to the third clavier is hardly open to serious question. It is not, in the author's opinion, a mutative corruption of the old word "chayre" (the birth-name which was assigned to it by its originators), for of course the old spelling of "choir" is "quire." The two names afford a good instance of terminological parallelism, representing two rival view-points, those of the organ-builder and the organist respectively. To the builder's mind the name "chair" would be suggested by the *position* of the pipes, sound-board and mechanism of the organ, the pipe-work and sound-board being erected *behind* the organ-seat, and the tracker-work and draw-stop action being connected *underneath* the seat; while the player would naturally associate this group of stops with the "choir," whose voices they were specially designed to accompany. But it is obvious that the modern choir organ, above described, has little or no claim to this title, since it is not so specially adapted to the requirements of vocal accompaniment as to be distinguishable in this respect from the other departments of the instrument. There is much of the old English organ-builders' pipe-work which modern artists can ill afford to lose. The beautiful low-pressure diapasons and stopped flutes of the seventeenth and eighteenth centuries are well worthy of imitation, and their growing obsolescence is much to be deplored. The author has made a personal effort to resurrect these early types of voicing by re-introducing them into several organs for whose tonal scheme he

has been responsible (see Chapter III. on Diapasons). To set apart a special group of these stops on an open sound-board and to make them playable on the third manual is the duty of the present-day designer: thus shall we ensure the survival of the old "chayre organ" and provide the organist with a really useful set of accompanimental stops which may justly be called a choir organ. The third manual may, however, also contain an enclosed echo group, and, if no fourth clavier be provided, an enclosed orchestral division, though these extra groups need by no means be playable exclusively on this clavier.

The following is a sample specification of a *real* choir organ:

Double Dulciana, 16 ft.
Early English Diapason, 8 ft.
Stopped Flute, 8 ft.
Principal, 4 ft.
Nason Flute, 4 ft.
Twelfth, $2\frac{2}{3}$ ft.
Fifteenth, 2 ft.
Mixture, 19, 22.

In a large organ, a couple of chorus reeds, 16 ft. and 8 ft., could be added to this group, voiced to match the flue stops, and thus a very delightful imitation of the old cathedral great organ would be obtained. The whole of this work should be unenclosed.

4. The *Echo Organ* consists primarily of enclosed soft flue stops, but the inclusion of soft reeds is permissible, though, if the pipe-work be planted on a sound-board in close proximity to the main organ, it is difficult to decide whether the reeds should belong to this department or to the solo organ. In the case of a "celestial" or echo organ placed in some remote corner of the church, such as in the triforium or at the back of the reredos, a complete tonal scheme of flue- and reed-work is indicated, as it is intended to be used in *contrast* to rather than as supplementing the rest of the organ.

A sample scheme for an echo organ follows:

Flue-Work.	Reed-Work.	
Bourdon, 16 ft.	Double Clarinet, *or*	16 ft.
Open Diapason, 8 ft.	Contra Oboe,	

FLUE-WORK—*continued.*	REED-WORK—*continued.*
Viole Sourdine, 8 ft.	Echo Trumpet, 8 ft.
Unda Maris, 8 ft.	Harmonics, 12, 15, 17, 19, 21, 22.
Echo Flute, 8 ft.	
Octave Diapason, 4 ft.	
Flauto Traverso, 4 ft.	
Harmonic Piccolo, 2 ft.	

5. The *Solo Organ* is, as its name implies, a collection of solo and orchestral stops, reed and flue. As a matter of fact the conventional designer does not group all the solo and imitative tones of the organ in this division, for he puts the oboe and vox humana in the swell and frequently the string stops as well; the clarinet and the 'cello he assigns to the choir organ, and the solo manual itself usually contains the following group of stops:—concert flute, 8 ft. and 4 ft.; cor anglais, 16 ft. or 8 ft.; orchestral oboe, 8 ft.; tubas, 16 ft., 8 ft. and 4 ft. (the last three being sometimes known as the "tuba organ," as at S. Paul's Cathedral, London). The clarinet or corno di bassetto and the viols occasionally find a place in this department, but are in this case usually duplicated in another part of the organ.

The real reason why these inconsistencies are perpetrated is because the grouping of *all* solo stops on a single clavier seriously affects their value and usefulness unless each one can be made independently available on at least one other manual, and this latter arrangement forms no part of the conventional scheme. So long as the clavier is allowed to remain the prison-house in which all its tone-colours are confined, it will never be possible to make any real progress in console design. It will not be necessary to give a list of stops belonging to the solo organ. The reader is referred to Chapter III., where the orchestrally-imitative stops are mentioned.

6. The *Pedal Organ* has only of recent years received due recognition at the hands of organ-builders. Its poverty-stricken condition was the result of a false conception of its relationship to the manual-work of the organ. Once the true relationship was perceived the pedal organ was bound to be revolutionised. Everybody now realises that the pedal is the real bass of the organ and that consequently, to say the least, no manual 8 ft. stop of any importance should be deprived of

a suitable pedal bass. The appreciation of this desideratum has inevitably led to a free and unimpeded recourse to the borrowing of manual stops on to the pedal, both in unison and by octave extension. The playing of chords of more than two notes being impracticable on the pedal-board, and the pipes of this department being the most costly of the whole organ owing to their size, the practice of extensive borrowing and duplication may be amply justified on the ground of economy. Moreover, it is thus possible, without greatly adding to the cost of the organ, to introduce *enclosed* stops which may serve as appropriate pedal basses to the enclosed manual combinations. It would be wrong, of course, to exclude all independent stops from the pedal organ, but with the modern system of manual to pedal transmission, it would be quite sufficient to provide an open and a stopped 16 ft. with their extended octaves (making two extra octave stops) as independent pedal stops.

From the foregoing it will be seen that all the different groups which collectively constitute the organ as a musical instrument can be quite conveniently distributed over three or four claviers or manuals. Great strides have of recent years been made in the mechanical department of organ construction, and not the least important result of this development is the vastly increased possibilities of manual interdependence. In other words, it is now possible to arrange for any individual stop or group of stops to be playable on any clavier in any pitch, and this is saying a great deal. Moreover, the enclosure of various groups of tone-colours in different swell boxes need not affect their individual availability on any clavier.

A practical illustration will serve to make this more clear to the student. Let us suppose that we are asked to design a console bringing the following specification of manual tone-colours under the organist's control:

Great Organ.	Swell Organ.
Double Open Diapason, 16.	Double Trumpet, 16.
Open Diapason I., 8.	Trumpet, 8
Open Diapason II., 8.	Clarion, 4.
Open Flute, 8.	Harmonics, 8, 12, 15, 19, 22.

GREAT ORGAN—*continued.*

Principal I., 4.
Principal II., 4.
Flute, 4.
Twelfth, $2\frac{2}{3}$.
Fifteenth, 2.
Mixture, 19, 22.

ECHO ORGAN.

Open Diapason, 8.
Viole Sourdine, 8.
Unda Maris, 8.
Echo Flute, 8.
Octave Diapason, 4.
Octave Flute, 4.
Harmonic Piccolo, 2.
Contra Oboe, 16.
Oboe, 8.

CHOIR ORGAN.

Double Dulciana, 16.
Early English Diapason, 8.
Stopped Flute, 8.
Dulciana, 8.
Early English Principal, 4.
Nason Flute, 4.

SOLO ORGAN.

Contra Viòla, 16.
Viola, 8.
Violes Célestes, 8.
Violin, 4.
Concert Flute, 8.
Harmonic Flute, 4.
Cor Anglais, 16.
Clarinet, 8.
Contra Tuba, 16.
Tuba, 8.
Octave Tuba, 4.

The conventional method of arranging the manual stops would be in accordance with the following plan:

GREAT ORGAN (unenclosed).

Double Open Diapason, 16.
Open Diapason I., 8.
Open Diapason II., 8.
Clarabella, 8.
Principal I., 4.
Principal II., 4.
Harmonic Flute, 4.
Twelfth, $2\frac{2}{3}$.
Fifteenth, 2.
Mixture, 19, 22.

CHOIR ORGAN (unenclosed).

Double Dulciana, 16.
Open Diapason, 8.

SWELL ORGAN (enclosed).

Contra Viola, 16.
Open Diapason, 8.
Echo Flute, 8.
Viola, 8.
Violes Célestes, 8.
Octave Diapason, 4.
Violin, 4.
Mixture, 12, 15, 19, 22.
Double Trumpet, 16.
Contra Oboe, 16.
Cornopean, 8.
Oboe, 8.
Clarion, 4.

CHOIR ORGAN (unenclosed)—*continued.*

Stopped Diapason, 8.
Dulciana, 8.
Principal, 4.
Nason Flute, 4.
Viole Sourdine, 8
Unda Maris, 8
Flauto Traverso, 4
Piccolo, 2
Clarinet, 8
} enclosed.

SOLO ORGAN (enclosed).

Concert Flute, 8.
Harmonic Flute, 4.
Cor Anglais, 16.
Corno di Bassetto, 8.
Contra Tuba, 16.
Tuba, 8.
Tuba Clarion, 4.

And this, with an adequate pedal scheme to match it, would be considered a very fine organ indeed.

But there is another method which is commending itself to an increasing number of architects, and it will be readily grasped by anyone who makes a careful scrutiny of the subjoined four-manual and pedal scheme:

GREAT ORGAN.

Double Open Diapason, 16
Open Diapason I., 8
Open Diapason II., 8
Open Diapason III., 8 (Early English; from [Choir Organ)
Open Flute, 8
Flute, 4
Principal I., 4
Principal II., 4
Principal III., 4 (from Choir Organ)
Twelfth, $2\frac{2}{3}$
Fifteenth, 2
} On open sound-board on $3\frac{3}{4}$ in. wind.

Mixture, 15, 19, 22
Contra Tuba, 16
Tuba, 8
Octave Tuba, 4
} Bombarde Organ or Primary Chorus enclosed in Swell Box I., on 12 in. wind.

Harmonics, 8, 12, 15, 19, 22
Double Trumpet, 16
Trumpet, 8
Clarion, 4
} Swell Organ or Secondary Chorus enclosed in Swell Box II., on 7 in. wind.

Swell Organ.

Contra Viola, 16 Viola, 8 Violes Célestes, 8 Echo Flute, 8 Violin, 4 Octave Flute, 4 Octave Célestes, 4 Harmonics, 8, 12, 15, 19, 22 Double Trumpet, 16 Trumpet, 8 Clarion, 4	In Swell Box II., on 7 in. wind.
Open Diapason, 8 Concert Flute, 8 Octave Diapason, 4 Harmonic Flute, 4 Harmonic Piccolo, 2 Contra Oboe, 16 Oboe, 8	In Swell Box I., on $3\frac{3}{4}$ and 7 in. wind.

Choir Organ.

Double Dulciana, 16 Early English Diapason, 8 Stopped Flute, 8 Dulciana, 8 Early English Principal, 4 Nason Flute, 4	Unenclosed "Chayre" Organ on $2\frac{1}{2}$ in. wind.
Open Diapason, 8 Viole Sourdine, 8 Unda Maris, 8 Octave Diapason, 4 Harmonic Piccolo, 2 Contra Oboe, 16 Oboe, 8	In Swell Box I.

CHOIR ORGAN—*continued.*

Echo Flute, 8 Octave Flute, 4 Cor Anglais, 16 Trumpet, 8 Clarinet, 8	In Swell Box II.

SOLO ORGAN.

Concert Flute, 8 Harmonic Flute, 4 Harmonic Piccolo, 2 Harmonics, 15, 19, 22 Contra Tuba, 16 Tuba, 8 Octave Tuba, 4	In Swell Box I.
Viola, 8 Cor Anglais, 16 Trumpet, 8 Clarinet, 8	In Swell Box II.

PEDAL ORGAN.

Sub Open, 32
Open I., 16
Open II., 16
Sub Bass, 16
Dulciana, 16
Octave, 8
Flute, 8
Dulciana, 8
Superoctave, 4
	On open chests.

Oboe, 16 Tuba, 16 Octave Tuba, 8	In Swell Box I.
Violone, 16 Viola, 8 Trumpet, 16 Clarion, 8	In Swell Box II.

Here we see that several of the stops have been duplicated and made available on more than one clavier, and also that certain groups have been enclosed in separate swell boxes in accordance with a definite scheme of differentiation. Underlying the whole design is the desire to secure the maximum service from a given number of tone-colours Such an arrangement necessarily increases the number of stop-knobs on the jambs, but those who adduce this factor as an argument against the duplication system will do well to bear in mind the following considerations:

1. The need for manual couplers (octave and unison) is considerably lessened.
2. It is possible to play "full organ" on the great manual without disturbing any combination of stops that the organist may have drawn on the other manuals.
3. Hand-registration is reduced to a minimum by the provision of a set of pistons actuating stop-combinations on each manual, and these piston-controlled combinations need not be fixed by the builder but can be arranged in any order of combination and permutation by the player himself by means of a system of adjustable locking knobs.

So far we have only dealt with the question of *unisonal* duplication; but on the pedal clavier a system of *octave* extension is also employed, even by the most conservative firms, the 8 ft. stops being derived from the 16 ft.

Now there is a school of architects who are prepared to carry this system of octave extension to greater lengths and to apply it to the manual stops as well as to those of the pedal organ, the object being to diminish to a considerable extent the number of pipes employed in the organ. It must be carefully borne in mind that all stops or groups of stops designed for duplication, whether unisonal or octaval, should be placed on separate sound-boards, and that each sound-board requires its own set of pallets and pneumatic motors, and receives its own wind supply direct from the reservoir. A large sound-board may be divided into two or more sections by means of one or more sectional cross-bars, but each section demands its own set of

pallets and action-motors, so that this can only be a device to save room and material.[1] A series of bi-sectional chests provided with removable face-boards at either end would seem to be the best arrangement (see Chapter I., p. 16).

Now instead of constructing a three-slide sound-board to hold three stops of the same family of 16 ft., 8 ft. and 4 ft. pitches respectively, each stop comprising 61 pipes, thus :

16 ft. stop (say double open diapason), 61 pipes
8 ft. stop (say open diapason), 61 pipes
4 ft. stop (say principal), 61 pipes

it is possible to construct a single-rank sound-board containing 85 pipes from 16 ft. to 4 ft. (*i.e.* seven octaves), thus :

85-note chest holding seven octaves of diapason pipes from CCC to top C

To this sound-board is fitted sub-octave, octave and unison off couplers, so that when the sub-octave and unison off couplers are in use only the 16 ft. register (double open diapason) is playable ; when the octave and unison off couplers are drawn, only the 4 ft. register (principal) is playable ; and when no coupler is in use, the 8 ft. register only (open diapason) is playable. Now the stop-knobs of the great organ, labelled double open 16 ft., open diapason 8 ft., and principal 4 ft., can be made to operate the sub-octave and unison off couplers for the 16 ft., the octave and unison off for the 4 ft., and to render inoperative the unison off coupler in order to produce the 8 ft. These registers can also be made available on any other manual by means of pneumatic duplication. As a matter of fact the diapason is the worst possible stop to submit to such treatment, and if it is a matter of necessity through urgent considerations of space, it is best to apply the

[1] And when we come to consider the necessity of making these separate sections accessible for repairs, the actual gain in space is highly questionable.

process to a secondary diapason such as the early English diapason of the choir organ above specified, and to borrow the 16 ft. register on to the great organ to provide the double open 16 ft. on that manual, making the 8 ft. and 4 ft. registers available on both choir and great.

The swell 16 ft., 8 ft. and 4 ft. reeds can be derived from a single-rank 85-note sound-board in exactly the same way, and similarly the following families of stops may be treated:—violone 16 ft., viola 8 ft. and violin 4 ft.; contra oboe 16 ft. and oboe 8 ft.; concert flute 8 ft., 4 ft. and 2 ft.; tubas 16 ft., 8 ft. and 4 ft.; echo flute 8 ft. and octave flute 4 ft.; stopped flute 8 ft. and nason flute 4 ft.

By this means a considerable saving of pipes can be effected, for the total number of pipes demanded by the conventional system for the diapasons, reeds, flutes and strings belonging to the organ above specified is 2892, while by adopting this other method only 1853 pipes would be required, thus reducing the total by 1039. It is also argued in favour of the "unit system," as it is now called by its supporters, that as separate sound-boards are necessitated in all cases where manual stops are borrowed on to the pedal, the extra expense involved in constructing these extension chests and fitting octave and unison off couplers to them is practically counterbalanced by the saving of pipe-metal. With careful and artistic voicing, it is claimed that even an expert ear would find it difficult to determine whether the conventional or the unit system had been employed. As a matter of fact it is very questionable whether any saving of expense is effected by the unit system; the only real economy lies in the direction of *space*. Obviously it is easier to pack 1853 pipes into a small space than it is to pack nearly double the number, and if it were not for the fact that church architects so rarely provide adequate room for the organ in their church building schemes, the unit organ would not have earned the support it now enjoys. Consequently, where space is strictly limited and the building itself is large and demands a larger instrument than can be accommodated on conventional lines, there is no option but to fall back on the unit system. In this case it must be borne in mind that the greatest possible care must be exercised in the treatment of pure organ tone, and that more latitude is admissible in the case of reeds, strings and especially flutes.

To sum up: unisonal duplication of manual stops is not only

defensible but compatible with the laws of art: *octave extension* of manual stops is only defensible on economical grounds, and even then must be adopted with caution, separate sound-boards readily accessible for repairs being essential to success, and the voicing and finishing of the stops thus treated being most carefully attended to.

In this chapter the *fundamental principles* of organ tonal design have been enunciated and explained. No student who has not mastered these principles can hope to design a successful organ. It will thus be seen how important it is to entrust the specification of a new organ to none but an experienced architect who is not only able to prepare the best possible scheme to suit the requirements of any building, but is also able to supervise its execution if so desired.

The time will surely come when all who are interested in organs and their construction will have reached a far higher standard of knowledge and aural discrimination than is possessed by the average musician of to-day. Then the player will demand better things, and the engineer, the architect and the voicer, that triumvirate on whose co-operation the success of the organ ultimately depends, will be glad to lay at his feet the fruits of their labour and experimental research. So shall organist and organ-builder work together for the common ideal, and in every shrine that is consecrated to the worship and glorification of God shall be heard the richness, the beauty and the majesty of the multi-coloured voices of the Church's own Instrument.

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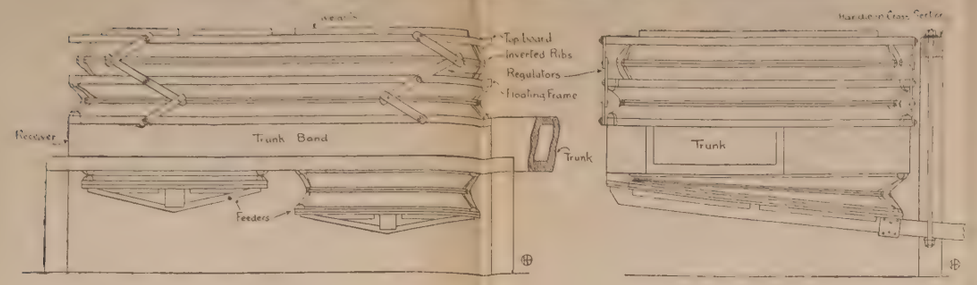
Fig 1 - Compound Double Rise Hand blown Bellows - Front and Side Elevations



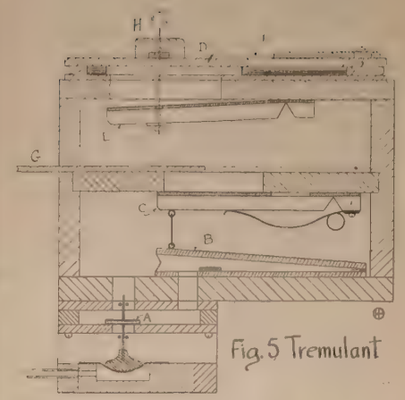


Fig. 5 Tremulant

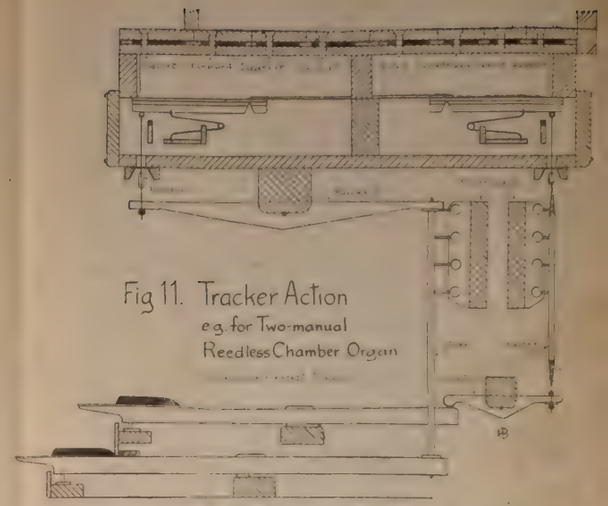


Fig 11. Tracker Action
e.g. for Two-manual
Reedless Chamber Organ

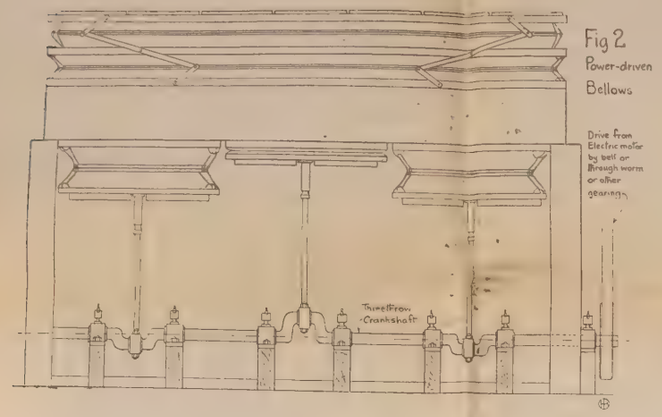


Fig 2
Power-driven
Bellows

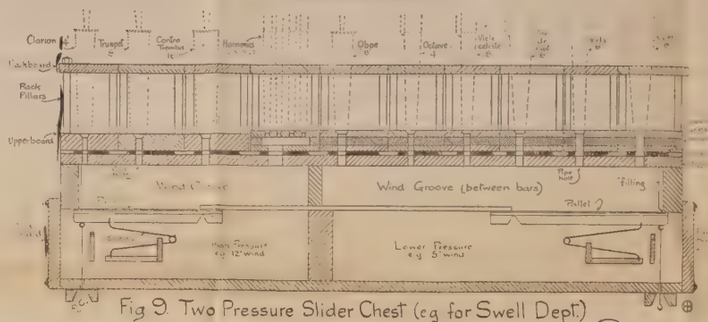


Fig 9. Two Pressure Slider Chest (eg for Swell Dept.)

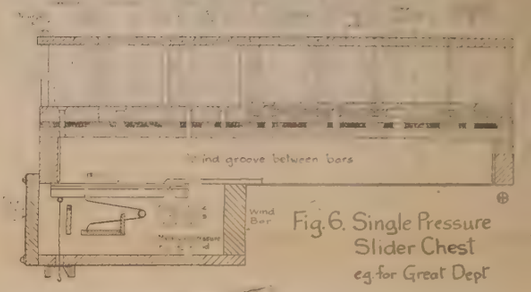


Fig. 6. Single Pressure
Slider Chest
eg for Great Dept

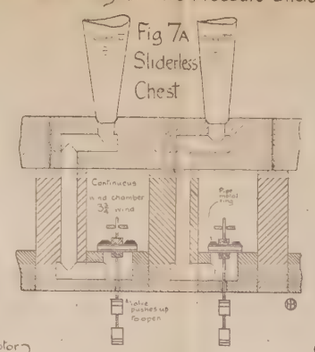


Fig 7A
Sliderless
Chest

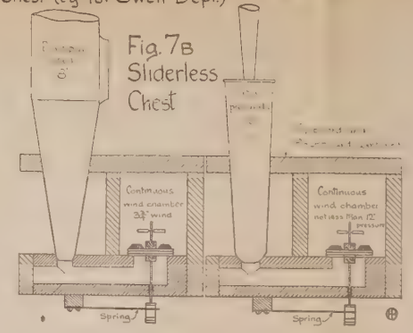


Fig. 7B
Sliderless
Chest

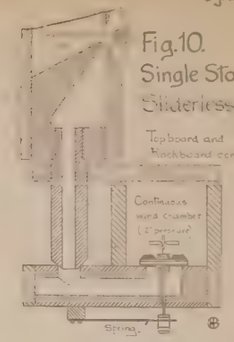


Fig. 10.
Single Stop
Sliderless Chest

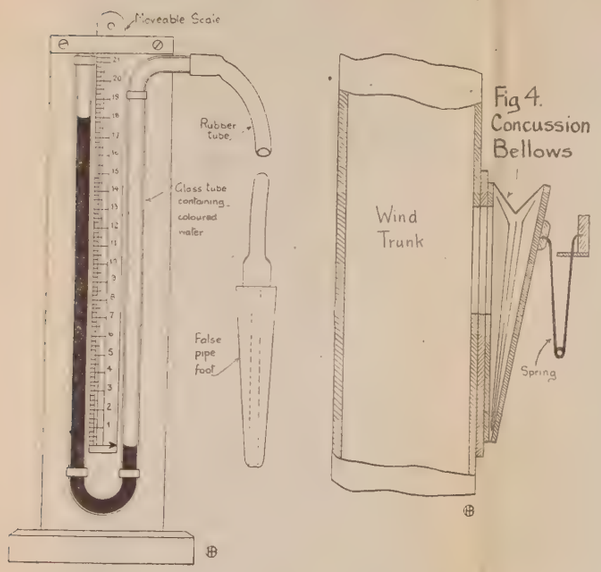


Fig. 4.
Concussion
Bellows

Fig. 3. Windgauge

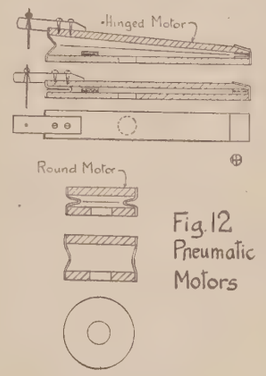


Fig. 12
Pneumatic
Motors

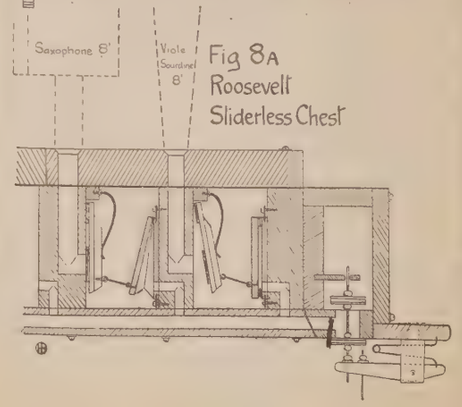


Fig 8A
Roosevelt
Sliderless Chest

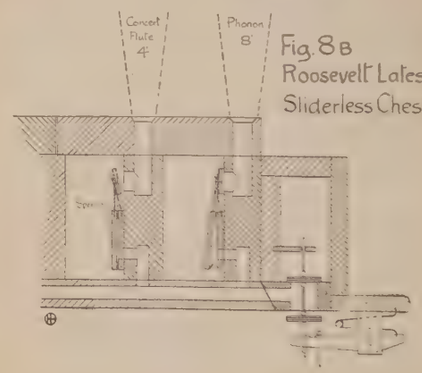


Fig. 8B
Roosevelt Latest
Sliderless Chest

Fig 13 – Barker Pneumatic Lever
(Cavaillé-Coll Organ)

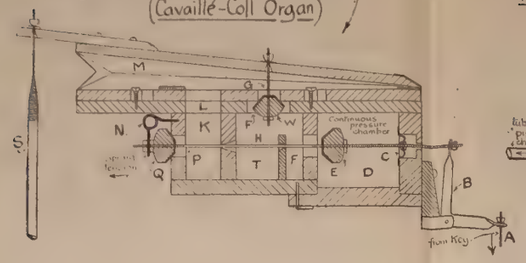


Fig. 18 – Pressure Relay

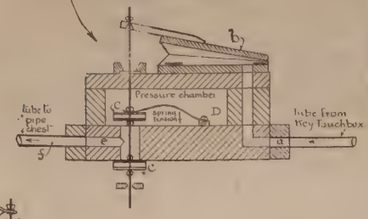


Fig. 23. Pressure Key-Touchbox

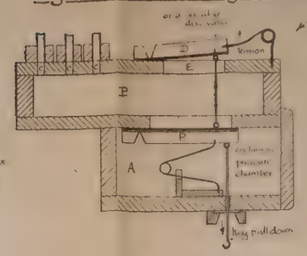


Fig 28 – A Type of Pneumatic Drawstop Action
(Holt, Walsall)

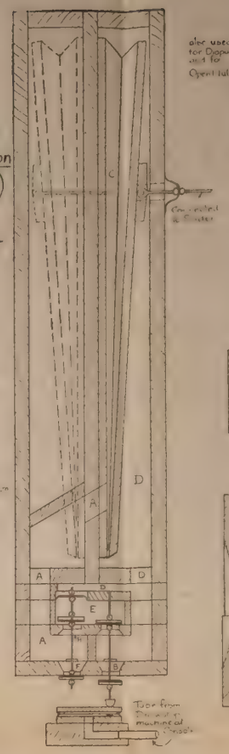


Fig 33b. German Gedeckt

Fig 32c. metal pipe inverted languid

Fig 32a. metal pipe modern languid

Fig 32b metal pipe Early English languid

Fig 33c. Waldflöte

Fig 33a. Old English Stopt Diap^n

Fig 34 a. Binns Wood Diapason

Fig 33d Schulze Diapason (Armley)

Fig. 34 b. Schulze Diapason (Hindley)

Fig 34c. Schulze Violonbass (Hindley)

Fig 34 d. Pendlebury Diapason or Violin

Fig 14 – Relief Motor-Pallet
(Probably the father of all Inside-Pallet-Motor Pneumatic Systems)

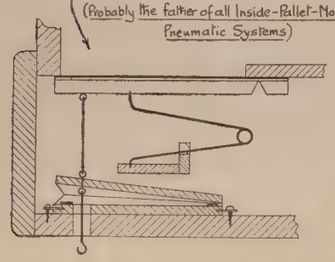
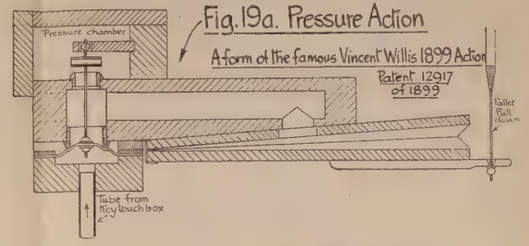


Fig. 19a. Pressure Action
A form of the famous Vincent Willis 1899 Action
Patent 12917 of 1899



Tubes to distributor

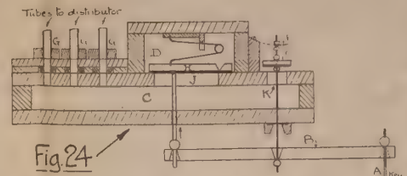


Fig. 24
"Floating Lever" Pressure Key-Touchbox

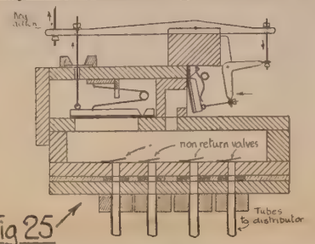


Fig 25
Vacuum (i.e. "Forced Exhaust") Key-Touchbox
(Can also be used for "Pressure" by omitting non return valves)
The note being "off" in the Fig., the non-return flapvalves should be closed. They are shown open (as when note is on") so that they may be better seen.

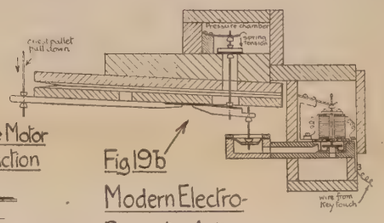


Fig 19b
Modern Electro-Pneumatic Action
This is one form of the fine action fitted to the Liverpool Anglican Cathedral Organ
Henry Willis Junr. Eng. Patent 12951 of 1915

Fig 15 – Double-Motor Pressure Pneumatic System

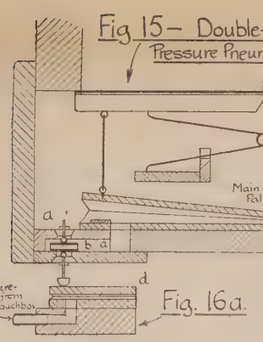


Fig. 16a.

Fig 20 – Triple Motor Exhaust Action

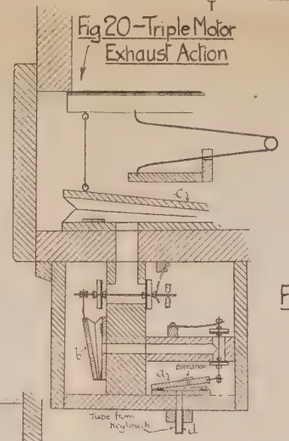


Fig 21 – Exhaust Key-Touch

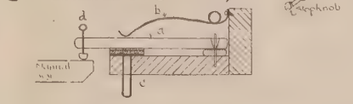
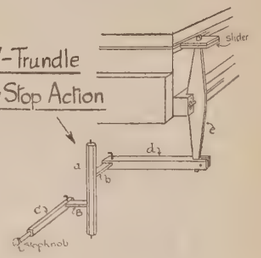


Fig 27 – Trundle Draw Stop Action



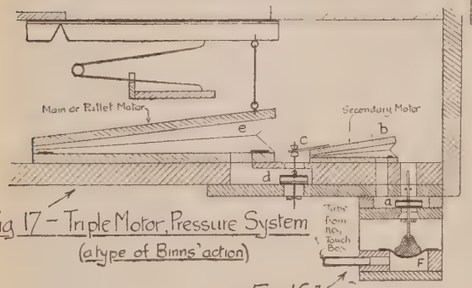


Fig 17 – Triple Motor, Pressure System
(a type of Binns' action)

Fig 16b

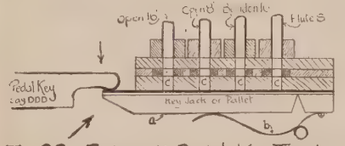


Fig 22 Exhaust Pedal-Key-Touch

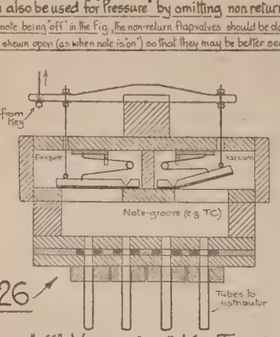


Fig 26
Pressure "off", Vacuum "on", Key-Touchbox

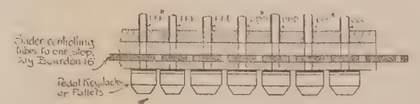


Fig 29 – Pedal Exhaust-Touch-Box
Section taken behind Pedals, looking from back to front of Console, viz. at right angles to that shewn in Fig 22.

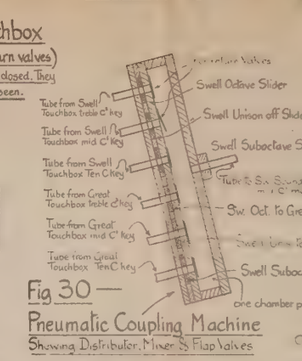


Fig 30 –
Pneumatic Coupling Machine
Showing Distributor, Mixer & Flap Valves

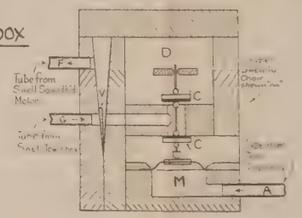
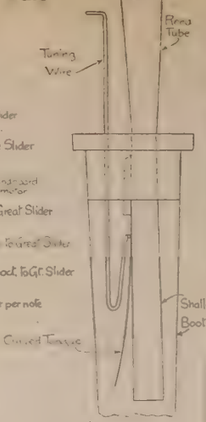


Fig 31 – Pneumatic (Pressure) Coupling Machine with "V" non-return Valves



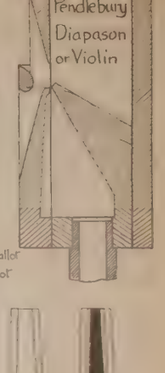


Fig 35a – Striking Reed
Fig 35b – Closed Shallot
Fig 35c – Open Shallot

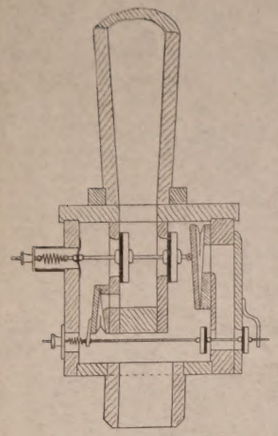


Fig 36a - Diaphone (Motor type)
Hope Jones Pat. 21558/'95

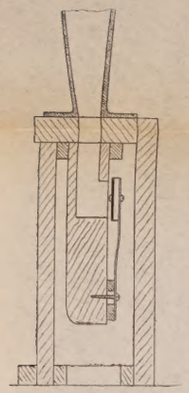


Fig 36b Diaphonic Horn

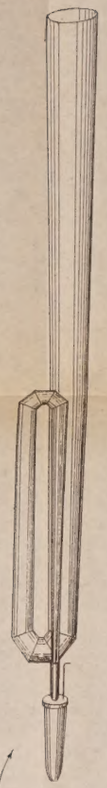


Fig-37
Mitred Reed
(Trombone, CCC pipe)

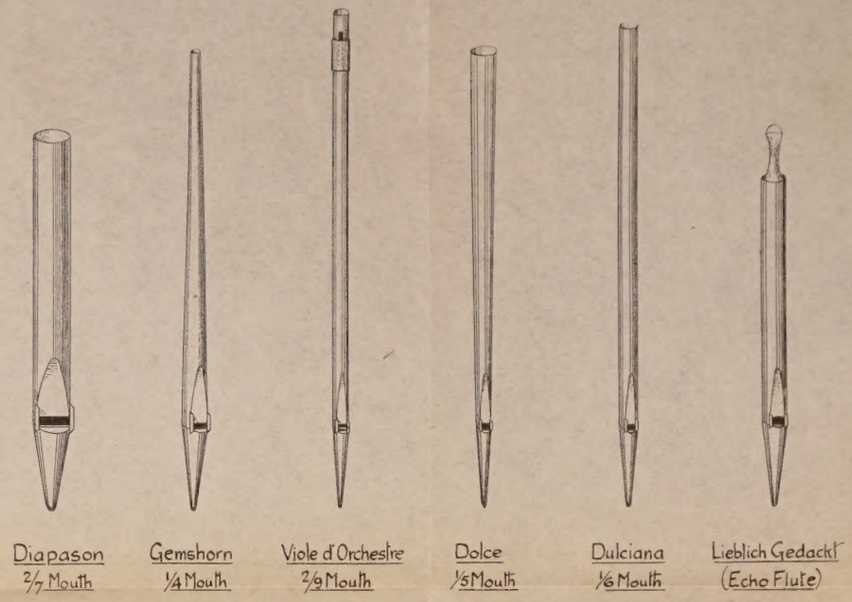


Fig 38 - Examples of Metal Flue Pipes

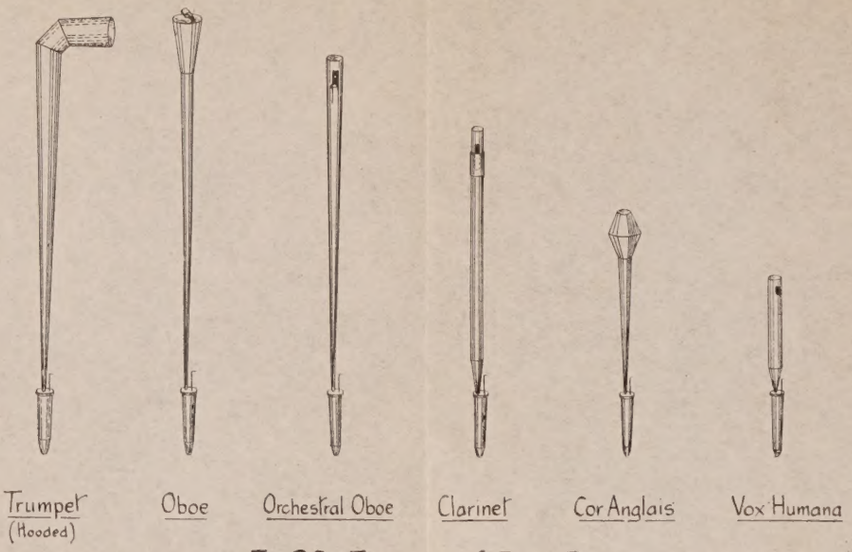
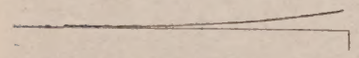
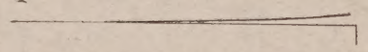


Fig 39 - Examples of Reed Pipes

Fig 40 Curves of Reed Tongues



High Pressure Curve



Low Pressure Curve

2015

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